



A Bibliometric Analysis of Wicked Problems: From Single Discipline to Transdisciplinarity

Xiaojing Hou¹ · Ruichang Li¹ · Zhiping Song¹

Received: 15 April 2021 / Accepted: 15 March 2022 / Published online: 6 April 2022
© Fudan University 2022

Abstract

With the increase of social complexity and uncertainty, wicked problems have become the hot and difficult issues in the frontier research of public policy. The concept of wicked problems was proposed in the 1960s. Since then, it has gradually spread to many disciplines, such as environment, urban planning, public policy, etc. A comprehensive understanding of the research progress of the transdisciplinary method is an important way to understand wicked problems. This paper uses Citespace5.5, based on bibliometrics and visual analysis techniques, to analyze 800 academic publications related to wicked problems and visually display the transdisciplinarity knowledge map and information panorama of wicked problems. Through a multi-level descriptive analysis of key literature, research origin, research hotspots and trend of the research on wicked problems, this paper finds out the law of knowledge growth and internal evolution logic of the research on wicked problems, and concludes that the transdisciplinarity research of wicked problems is forming, which shows the rule from knowledge diffusion (single discipline) to knowledge coherence (transdisciplinarity). The discipline of public policy has the potential to change the knowledge constraints of a single discipline and may offer transdisciplinarity approaches to wicked problems.

Keywords Wicked problems · Knowledge map · Transdisciplinarity research · Bibliometric analysis

1 Introduction

With the increase of social complexity and uncertainty, human beings face more wicked problems in an open social system, such as environmental pollution brought by the use of fossil fuels and the safety threat posed by genetically modified food. The concept of wicked problems derived from the field of planning was first

✉ Zhiping Song
469367600@qq.com

¹ School of International Relations and Public Affairs, Fudan University, Shanghai, China

proposed by Horst Rittel, professor of design, in a seminar of the Department of Architecture at the University of California, Berkeley, in 1967. It refers to complex and difficult problems that lack a complete definition or final solution (Rittel and Webber 1973). Wicked problems have been introduced to many disciplines such as business management, environmental governance, education, sociology, public policy, international relations, etc., and has attracted widespread attention from the academic community in many disciplines.

Scholars have explored the origin of the wicked problem concept and discussed its definition, classification, and solution based on their subject knowledge, which makes wicked problems have transdisciplinary characteristics (Camillus 2008). Some critical theoretical, conceptual, and empirical issues have been put forward in the academic literature, but lack consensus. Because fragmented but interconnected social challenges coexist, wicked problems call for cooperation among different disciplines, and they are against purely rational and mono-disciplinary knowledge.

As for the definition of wicked problems, there is a lack of clear explanation. The academic circles mostly summarize the characteristics of wicked problems from the perspective of epistemology, and then distinguish wicked problems from other social problems from the perspective of typology. The characterization of wicked problems breaks through the knowledge category of a mono-discipline. Early studies tend to regard wicked problems as a special kind of policy problem, which is the opposite of a tame problem. However, the systemic complexity and transboundary of the wicked problem is still not recognized. Rittel and Webber (1973) defined ten attributes of wicked problems, believing that it is difficult for wicked problems to be solved thoroughly and that it can only be dealt with continuously. Because of the mischievous and even evil nature of wicked problems, the solutions proposed are often worse than the symptoms. Some scholars have tried to define “super wicked problems” by adding additional criteria (Lazarus 2009; Levin et al. 2012). Most scholars, who work on wicked problems, try to reduce the ten criteria to fewer distinguishing features. Roberts (2000) condenses Rittel and Webber (1973) problem-related features and solution-related features. Then, the wicked problem concept is defined by two dimensions: lack of consensus problem definition, plus lack of consensus solutions. Xiang (2013) condensed ten features into five features: indeterminacy in problem formulation, non-definitiveness in problem solution, non-solubility, irreversible consequentiality, and individual uniqueness. Recent research goes beyond the dichotomous analytical framing of wicked versus tame problems, albeit in different ways. Most authors hold that wicked problems are made up of multiple internal characteristics, all of which can be divided on different scales from docile to intractable, as differences between facts and values combination (Hunter 2007). This point of view reflects the realization that wicked problems are not a special kind of problem, but systematic and continuous problems. These problems present major challenges for coping as they cross the boundaries between countries, policy domains, organizations, and scientific disciplines, as they are situated in transnational spaces, with overlapping jurisdictions, interlinked policy spheres, fuzzy or ambivalent ethical standards, and much contestation, threat, aggression, emotion and fear, as well as time pressure. The transboundary of the wicked problem also reflects indirectly that the knowledge involved in wicked problems has the characteristics of coherence.

Head and Alford (2015) emphasized that wickedness is a degree of problem, and attributed wickedness to a combination of complexity, diversity, and uncertainty. They advocated that wicked problems should be regarded as a problem spectrum or divided into more sophisticated problem types. Weber and Khademian (2008) thought the concept of wicked problems is unstructured, and includes multiple, overlapping, and interrelated subsets of problems that span various policy areas and government levels, and are relentless (Turnbull and Hoppe 2019).

There is no denying that the concept of wicked problems is a valuable concept, which reveals the inapplicability of the reductionist approach and the linear problem-solving approach while solving complex social problems (Xiang 2013; Lönngren 2017). Besides, knowing what true wicked problems are is an essential prerequisite for solving them. The analytical distinction between wicked problems and tame problems is an interesting answer to the government's attempt to divide, organize, and rationalize the world's problems. Normally, a policy issue will be called wicked by policy makers when it is difficult to make even gradual progress on its normative and factual issues, because the distance between the parties involved is still large and there are often conflicts. Scholars criticized the essentialist perspective of focusing on the problem itself, and clarified that the existing research does not pay much attention to the complexity of the systems in which wicked problems are intertwined, and the wickedness of the complexity of the systems does not stem from various problems being just interrelated with each other, but from being in constitutive dynamic relations with each other (Selg et al. 2021). This adds to the problem of dealing with them, and transdisciplinary approaches would be helpful. But we found that the study of wicked problems ignores the transdisciplinary nature of the problem itself. According to the frontier research, Selg et al. (2021) saw the intersection between governance and public administration, and sociology for developing a processual-relational methodology as a transdisciplinary approach for studying wicked problems. They take COVID-19 as an example and argue that the specificity of processual relationalism lies in seeing these relations also as dynamic, unfolding processes, not as static ties. It means wicked problems should be studied as chains of trans-action that "can be considered separately, but not as being separate" (Dépelteau 2008; Elias 1978). Noordegraaf et al. (2017) argued that transboundary problems are extreme wickedness which go further than crossing the boundaries between agencies, interests and domains, because there are intense ambiguities. As a result, boundaries are confounded and are unclear, shifting, and perpetually redrawn. The reason why wicked problems are difficult to solve is because of transcending boundaries between action and reaction, transcending boundaries between spaces, and transcending boundaries between knowledge systems. Wicked problems are also intractable because they relentlessly intertwine different disciplines, logics and knowledge systems.

It is regrettable that the concept of wicked problems is ambiguous and lacks a precise definition, which can quickly become an alibi or excuse for the public sector's reluctance to tackle complex social problems (Noordegraaf et al. 2019). There is no doubt that society is facing more and more wicked problems. However, the diversity of society, the complexity of social problems, and the fragmentation of scientific or professional knowledge restrict the solution of wicked problems. Generally

speaking, defining the problem and solving the problem are two important stages of dealing with wicked problems. Nevertheless, one of the special features of wicked problems is that it is difficult to accurately define the problem, because the knowledge gap between different disciplines is large. The cognitive perspective of a mono-discipline is narrow, and it often pays more attention to the professional knowledge system, methods, viewpoints and data within the mono-discipline, and is selectively blind to knowledge outside the discipline. What is more, the debate on the definition of the problem stems from the difference in worldviews and preferences. In addition, wickedness theories are still quite abstract, and there are blind spots in people's daily experience and practice in dealing with wicked problems. The existing theory clarifies what needs to be done, but it does not clarify how and by whom, which creates problems for those who have to act in the face of wicked issues. And in the knowledge system of wicked problems, ideological, scientific, and philosophical positions always intertwine.

In fact, the construction of a mono-discipline led to the compartmentalization of scientific and professional knowledge and the lack of effective collaboration between scientists, professionals, and policy decision-makers, which caused incapacity to deal with wicked problems. Social constructivism holds that people give meaning and value to problems. From this perspective, wicked problems also arise from personal value judgments. Values are constructed, but facts are externally real. The social constructivist view separates science from social problems and affects people's understanding of the wicked problems that exist widely in the real world. From an epistemological point of view, the recognition and resolution of wicked problems are a process of reaching consensus. The wicked problem ontology is a fact, and when the wicked problem is socially constructed, the problem will always be associated with other elements, even completely unrelated factors. On the one hand, wicked problems represent moral or ethical standards (including norms, values, principles, ideals), and on the other hand, facts, data, knowledge or experience. Therefore, the characteristics of wicked problems can be summarized as a combination of wicked problems, including the factual/technical complexity (knowledge, norms) and the social complexity (interests, values, etc.) of the problem.

This paper argues that the root cause of the inability to accurately define wicked problems lies in the dichotomy between the facts and values of wicked problems. On the one hand, we define cognitive problems and solve problems from the perspectives of facts, data and experience, but ignore the value of the problems, which leads to fragmentation. On the other hand, facts, data, and experience are indeed more conducive to finding and identifying problems, but most of the time, the solution of wicked problems requires a balance of multiple values.

Current shortcomings of research on wicked problems are mostly conducted from the mono-disciplinary perspective, with the narrow vision of so-called experts who do not address essential issues but only professional problems isolated from their societal context. However, the wicked problem has transcended the mono-discipline. Take health problems as an example. The definition of health by the world health organization (WHO) is that it is not merely the absence of disease and weakness, but the best state of physical, mental, and social well-being (WHO 1946). However, this definition is idealized, and health will not only be affected by direct pathological

effects such as chemical and biological agents and radiation, but also affected by the social environment's change on the body and mind. It is difficult to fully grasp the characteristics and solutions of wicked problems from the mono-disciplinary perspective.

In the context of our research, wicked problems are complex and messy social problems which are difficult or impossible to solve because of the incomplete, contradictory, and constantly changing needs of multiple actors in various situations. Each problem interacts with other problems and is part of a system of interrelated problems. The solution to a mess can seldom be obtained by independently solving each of the composed problems (Ackoff 1974; Rittel and Webber 1973; Head 2019).

What needs to be clear is the difference between interdisciplinarity and transdisciplinarity. If we look at the root of the word, *interdisciplinary* and *transdisciplinary* have different meanings. According to Merriam-Webster, “inter” means “between, among, in the midst”. “Trans” means “on or to the other side of, across, or beyond”. Interdisciplinarity involving two or more academic, scientific, or artistic disciplines is the result of knowledge intersection or knowledge combination between disciplines, of interdisciplinary approaches where there is conjoining of the disciplines to develop a shared understanding of a theme or solution to a problem. Thus, interdisciplinarity revolves around themes or problems where the focus is on commonalities between disciplines. As for interdisciplinary research, it focuses on scientific research that involves a number of disciplines to provide a systemic outcome. Interdisciplinary contributions can be interpreted as the bringing together of disciplines which retain their own concepts and methods that are applied to a mutually agreed subject. Interdisciplinary research is the process of answering, solving or presenting a problem that is far broader and more complex than a single discipline can handle. Besides, interdisciplinary research is the integration of theories, methods, tools and concepts from multiple professional knowledge bases, and is a way of integrating different disciplinary fields, as well as researchers and practitioners, to improve innovative problem-solving skills and build a more comprehensive perspective to integrate insights from various disciplinary perspectives. Therefore, interdisciplinarity may cause chemical reactions due to the collision of different knowledge, which then generates new knowledge—and this is not inevitable, but it may only be a comprehensive interpretation of two or three disciplinary knowledge perspectives.

Comparatively, transdisciplinarity revolves around real-world experiences, without regard for discipline-specific understandings. And transdisciplinarity involves multiple disciplines in order to connect new knowledge and deeper understanding to real life experiences. Transdisciplinarity research is a research process that includes the practical reasoning of individuals with the constraining and complex nature of social, organizational, and material contexts (Lawrence 2004: 400). The final knowledge of transdisciplinarity is more than the sum of its disciplinary components, but developed within multiple worldviews (Somerville and Rapport 2002 ; Lawrence and Després 2004). Its contributions enable the cross-fertilization of ideas and knowledge from different contributors that promotes an enlarged vision of a subject, as well as new explanatory theories. Firstly, transdisciplinarity deals with problems that are defined from complex domains, such as genetically modified food safety or climate change. Secondly, transdisciplinarity research accepts local contexts and

uncertainty (Thompson Klein 2004). Thirdly, transdisciplinarity implies continuous communication, interaction, and close cooperation between researchers and research institutions in search of intellectual consistency rather than intellectual unity (Lawrence 2004). Finally, it is also an action-oriented method which generates collective wisdom to understand the actual world and bridges the gap between knowledge derived from research and the decision-making process in society (Ramadier 2004).

The transdisciplinarity research on wicked problems is scarce. Therefore, this paper uses Citespace5.5 to analyze wicked problems from a transdisciplinarity perspective. More specifically, this paper attempts to answer the following questions:

- (1) What is the current transdisciplinarity research status of wicked problems?
- (2) What is the path of knowledge evolution on wicked problems? How does the process of publishing more transdisciplinarity papers happen?
- (3) Is transdisciplinarity possible in the current situation?

2 Methodology and Data

Bibliometrics is a quantitative method to study literature. It can construct a network diagram of the relationship between knowledge by using information visualization technology. It takes literature as information nodes and is based on co-citation analysis and co-occurrence analysis (Chen et al. 2003). Bibliometrics can visually display the research status of a specific topic and identify the gaps in existing research by drawing the knowledge spectrum of literature related to a specific topic, which can promote further study of this topic (Grant and Booth 2009). Citation analysis reveals the phenomenon, process, and law of citation by analyzing the flow process of citation and citation of literature. By displaying the research topic and focus of the field, cluster analysis and collinear keywords can visually present the knowledge picture of the area. CiteSpace5.5 is a scientific bibliometric software, which focuses on analyzing the potential knowledge contained in scientific literature. It can provide functions such as keyword co-occurrence analysis, literature citation analysis, and literature cited analysis. It also can conduct multivariate, time-sharing, and dynamic visual analysis of literature citation, thus presenting the structure, rule, and distribution of scientific knowledge (Chen et al. 2003). As shown in Fig. 1, this section discusses the procedures required to conduct a comprehensive quantitative bibliometric-based review.

To obtain representative and comprehensive target articles, the data are retrieved from the three core databases of Web of Science (WOS): Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (A&HCI). Sample acquisition can be divided into four stages.

The first stage is the preliminary data retrieval. We retrieved 1106 papers by setting subject terms as the “wicked problem” or “wicked issue”, setting the publication date to all years, and setting the literature type to all types. The last retrieval date was September 20, 2019.

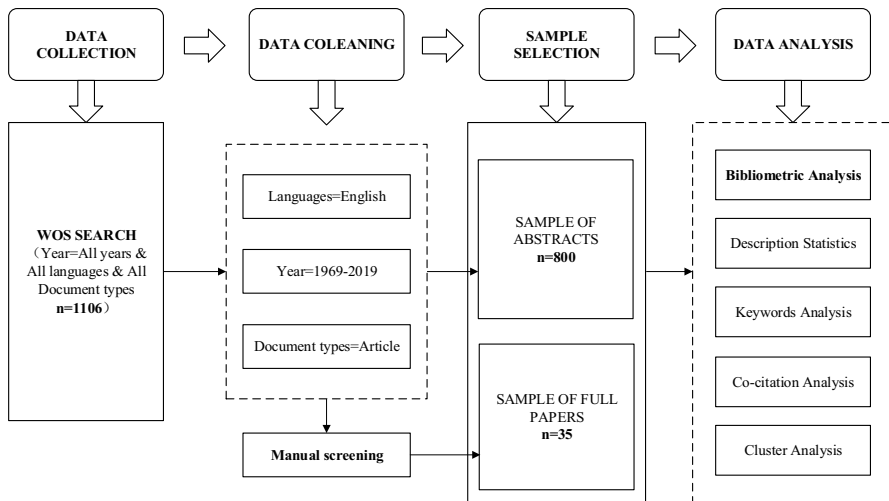


Fig. 1 The research methodology structure

The second stage is data cleaning and sample selection. Firstly, English is chosen as the language of literature considering that most studies on wicked problems are conducted in English-speaking countries. Secondly, considering that articles not only represent the academic interest but also can better reflect the influence of scholars on wicked issues, we chose the article as the literature type. Considering that the earliest academic paper on wicked problems was published in 1969, a total of 800 abstract samples were obtained after the time was shortened to 1969–2019. The sample involves ecology, environmental science, public policy and administrative management, design science and planning, business management, and other disciplines.

The third stage is presenting research hotspots. The research hotspot is the key for scientific researchers to track innovation trends and grasp research direction. It refers to very ground-breaking and leading research that is being widely discussed. Small and Griffith (1974) believe that the research hotspot is a group of highly cited papers. Therefore, we sorted the total citation frequency of 800 sample papers in descending order, and extracted the top 5% of the research literature. According to the title and keywords, we removed the repetitive and irrelevant literature that was not related to the research topic, and retained 35 highly cited documents to analyze research hotspots. Then, the baseline understanding and research controversy of wicked problems were presented by intensive reading of these 35 documents.

The fourth stage is bibliometric analysis. Considering the low volume of publications before 2000, this paper analyzes publication trends from 2000 to 2019 to acquire the research status and frontier progress of wicked problems. At the same time, this paper carries out a bibliometric analysis of the selected 800 papers to further reveal the comprehensive knowledge map of wicked problems. The current transdisciplinarity research status of wicked problems and the path of knowledge evolution on wicked problems were presented by bibliometric analysis.

3 Research Hotspots, Controversies and Frontiers

Before bibliometric analysis, an intuitive understanding of wicked problems is necessary. The knowledge base, hot topics, competitive views and frontier research on wicked problems can be presented through intensive reading of core documents (see Table 1).

At the beginning, what should be clear is the origin of wicked problems. At a seminar held at the University of California, Berkeley, in 1967, planning scholar Horst Rittel used the term “wicked problem” to refer to that class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing. The adjective “wicked” is supposed to describe the mischievous and even evil quality of these problems, where proposed solutions often turn out to be worse than the symptoms (Churchman 1967). In the planning, the research on wicked problems was concerned about the systematicness of municipal planning. Beginning from the 1970s, scholars in the policy and administrative sciences argued that social and policy planning problems are different from engineering technology problems. Engineering technology problems start from puzzles, which are typical tame and benign issues. Social policy planning issues are usually unclear and rely on political judgments rather than scientific determinations. Therefore, policy scholars are against purely rational approaches to policy. Forty years later, there is booming literature on wicked problems in science and technology studies. Pollution and other material externality crises in, for example, agriculture and food, health, forestry, water, and climate of the late twentieth and early twenty-first centuries broadened the circle of wicked problems to include environmental, technological and ecological issues. It not only derived a number of topics related to urban ecological management system, such as urban environment; sustainable development; ecosystem services; social ecosystem; urban ecosystem; infrastructure planning; adaptation to complex systems; sustainable ethics; etc. It has also expanded to other disciplines, covering cutting-edge research topics such as public health, food safety, water governance, e-government, social dependency, and other hot issues in public administration.

In the dimension of introducing and developing theories on wicked problems, scholars try to answer “What is so wicked about wicked problems?” to build the conceptual framework of wicked problems. In the research community, typologists try to clarify the differences between technical problems and social problems to state the definition and boundaries of wicked problems. Proponents of problem essentialism put their attention on the attributes utilized to characterize wicked problems. Regrettably, there has been no convergence on which problems are wicked nor characteristic. Some of them argue that the strict, ontological demarcation of wicked and tame problems according to the branches of science is a serious misconception (Turnbull and Hoppe 2019). They reject the notion of wicked problems as a special class of policy problems, and argue that the ten characteristics of wicked problems Rittel and Webber (1973) put forward all

Table 1 Three research paths on the wicked problems

Dimension	Examples of context	Key citations
Develop and introduce theories of the wicked problems	Types of the wicked problem (complexity; complex problem; messy problem; ill-structure problem) Characteristics of the wicked problem (uncertainty; completely) Conceptual framework of the wicked problem	Lönngren and van Poeck (2020), Alford and Head (2017), Peters (2015), Crowley and Head (2017), Head and Alford (2015), Hoppe (2009), Rittel and Webber (1973), Simon (1962), Jones and Baumgartner (2005), Klijn and Snellen (2009)
Empirical researches in multi-disciplinary of the wicked problem	Ecology/Environmental science; Climate change; Sustainable development; Social-ecological system; Energy; Water governance; food security; Health problem; Public administration/Public policy; Policy, Management, Administration; Business management; Post-normal technologies; Creative entrepreneurship; Economy; Leadership Planning; City planning; Complex software; Collective intelligence; Design thinking; Risk assessment	Bate (2008), Carroll et al. (2007), Fiksel (2003), Gibson and Tarrant (2010), Van Bueren et al. (2003), Jentoft and Chuenpagdee (2009), Renn (2008), Hendriks (1999), Bertolini (2010), Lazarus (2009), Xiang (2013), Conklin (2006a, b), Levin et al. (2012)
Tracking methods of the wicked problem	Ecology/Environmental science; Participation; Adaptation; Conversation; Transdisciplinary; Clumsy solution; Resilience thinking Public administration/Public policy; Problem framing; Muddling through; Collaboration; Governance; Network; Policy learning; Holistic approaches Business management; Innovation; small wins; Collective decisions Planning; Design process; Design thinking; Dialogue mapping	Roberts (2000), Van Bueren et al. (2003), Head (2008), Coyne (2005), Farrell and Hooker (2013), Fischer (1993), Weber and Khademian (2008), Ferlie et al. (2011), Brown et al. (2010), Allen (2013), Verweij et al. (2006)

express a common theme—the problematic nature of social problems and the persistence of their solutions, as well as the lack of systematic analysis to deal with these problems. But some scholars argued that there is a lack of clarity by drawing equivalent definitions between wicked problems and those that are “ill-structured” (Daviter 2017) or “ill-defined, ambiguous, and contested” (Termeer et al. 2015), not to mention the many other analogical terms used besides “wicked”, such as messy, fuzzy, complex or dilemmas (Bevir and Rhodes 2006; Roe 2013).

The second dimension is empirical research of wicked problems. Scholars situate their work in their own disciplinary and historical context to discuss what type of problem the wicked problem is. In the environmental management field, environmental scientists argue that problems resistant to today’s solutions are wicked. Environmental issues have time and space limitations from social politics and environmental systems, which will lead to fragmentation of environmental decision-making and instability of policies in larger geographical areas for issues like climate change, sustainable development, social-ecological system, water governance, etc. Policy scholars argue that many contemporary policy problems carry characteristics of wicked problems, which are ill-defined, ambiguous, contested, and feature multilayered interdependencies (Churchman 1967; Roberts 2000; Head 2008). This is because public policy has two continuing attributes, namely the political nature and the impossibility of the government to solve all problems. The biggest challenge for public policy is the difference of public value. Some scholars argue that we should situate wickedness from a street-level perspective that aims to complement the high-level understanding of wicked issues. This perspective helps shift the focus from wicked problems (wicked issues) to wicked situations, which refers to situations where involved people might feel wicked (Noordegraaf et al. 2019).

In the third dimension, scholars in different disciplines explore solutions to wicked problems based on the best knowledge that remains within their discipline. Natural scientists believe that natural resources and environmental issues have to face the fragmentation of environmental decision-making and policy instability in a larger geographic area which make them wicked. In addition, ecosystem restoration needs to be carried out over a long period of time, and the short-term nature of the socio-political process and changing social values will exacerbate the complexity of environmental issues (Balint et al. 2011). Therefore, they propose that participation, clumsy solution and resilience thinking ought to be used to cope with wicked problems which are based on principles of adaptability and precautions.

Policy scholars draw attention to conditions of the policy network in which actors operate to deal with wicked problems. The hypothesizing of public policy and public administration research is often: the higher the public’s participation, the higher the understanding of social development goals, and the greater the degree of personal application of the goals. Therefore, they propose muddling through, collaboration, governance, network, policy learning, and holistic approaches, etc. Turok (2014) believes that public policy formulation needs to consider what social problems should be solved, how to solve them, and what the possible consequences are. But in the field of public policy, policy makers are prone to try to solve a problem without knowing what it is.

Business management scholars emphasize collaboration. They regard managers as builders of collaborative capabilities, which build long-term collaborative problem-solving capabilities (Weber and Khademian 2008). Ferlie et al. (2011) discussed the governance impact in the healthcare sector, including inter-organizational learning, and horizontal leadership. Head and Alford (2015) also associate wicked problems with the need for strong governance and management capabilities, putting forward framework reflection and reconstruction, communication, trust, and adaptive leadership. Sabel and Zeitlin (2012) came up with experimentalist governance, which is based on mutual redefinition of purpose and means. Through an iterative, multi-level supply target setting and revision cycle, network governance practices that are clearly fluid provide a structure that can effectively deal with severe problems.

Existing research has provided a much more fertile breeding ground for wicked problems. Regrettably, there are very few views on how public officials, experts, professionals, citizens, civil society organizations, and social enterprises can really work together to carry out border work. There are still too few interdisciplinary contributions, and transdisciplinary contributions are even harder to find. Most scholars take wicked problems into the specialization of academic disciplines to think of coping methods, using disciplinary concepts and methods to explain the real world. The continuity and system of knowledge is often ignored and fragmentation caused artificially. Coping with wicked problems requires entering into complex heterogeneous domains where there are not only multiple constructions of knowledge, but they are also developed within multiple worldviews. Therefore, the transdisciplinarity is a synergy of new methods, with enriched understanding of wicked problems.

4 Bibliometric Analysis

Descriptive statistical analysis and bibliometric analysis can intuitively present the research status of wicked problems. Firstly, the paper describes the output and research trends on wicked problems in the past 20 years from time distribution.

4.1 The Stages of Wicked Problems: Specialization & Inclusive Knowledge Production

In terms of the number of articles, the research on wicked problems has shown two development stages since 2000 in Fig. 2. The first stage was the exploratory research period before 2007. The research on wicked problems is rare, with the number of articles maintained below 10 per year. It shows that the research on wicked problems was still in its infancy, and the related issues had not attracted widespread attention from scholars before 2007. The second stage is the diffusion stage since 2008. During this period, research on wicked problems increased significantly. After 10 years of development, the number of published articles reached its peak in 2017, totaling 128 articles, indicating that the topic of wicked problems has received extensive attention from scholars. The number of papers reached 115 in 2018. After the last

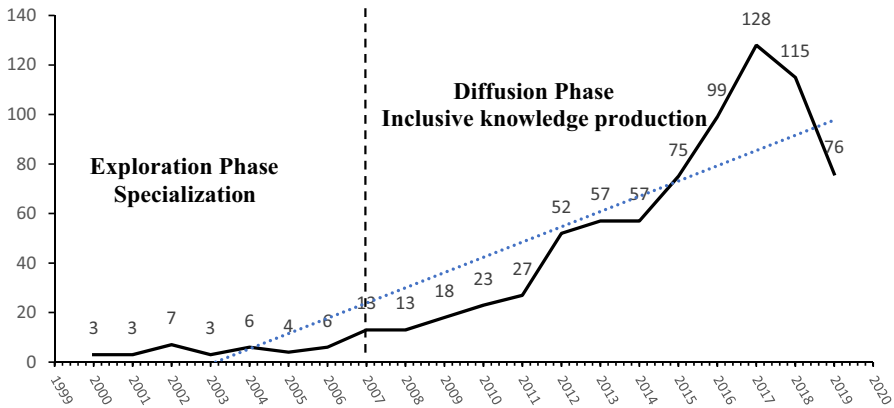


Fig. 2 The annual quantity of publication from 2000 to 2019

retrieval date of September 20, 2019, we searched the literature again and found many new literatures, which confirmed that the research on wicked problems is receiving more and more attention in academia. The study on wicked problems can be divided into two stages, and the dividing line is the proposal of the specialization of academic disciplines and inclusive knowledge production.

The first stage is the era of rationality and specialization. The discipline-based studies there are procedural rules. The nature of the problem was identified by experts or bureaucrats. From the perspective of experts, rationality is supreme, and experts regard professional skills, professional disciplines, and professional knowledge as preconditions for analyzing public issues. They advocate the establishment of authority and the use of expert knowledge to create an orderly social and material production process. But there are huge differences in professionalism in terms of knowledge, practicality, and stability. Experts tend to use rational tools and models to develop professional judgments, provide professional research for problem understanding, and conduct professional reviews of problems, fostering “elitism” and “professionalism”. Under professionalism, professionals do professional things, pursuing efficiency and managerialism. In this situation, technology and professional knowledge are superior. The best way to solve a problem is to follow a top-down linear procedure, and proceed in accordance with the logic from problem understanding to solution, which is named the waterfall model. People will understand how complex and important the problem is, especially in large organizations. The waterfall model is often regarded as a shrine and becomes an internal standard for project management. The premise of the waterfall model is that the threshold of the problem, the correct solution procedure, the solution tool, and the solution method are known (Conklin 2006a, b).

The second stage is accompanied by the emergence of inclusive knowledge production. Diversity, dynamics, and complexity are the core characteristics of contemporary society. The social-political system is increasingly divided and flooded with multiple centers. In this system, various actors are connected and are constantly being shaped through communication and interaction. Multinational

institutions are neatly organized together to build networking relationships (Holton 2007). The network contains a more lasting social commitment and trust than the market mechanism, and it is more flexible and more decentralized than the hierarchical system. Some scholars have suggested to take full account of the complexity of a wicked problem; to accept social and physical realism; to acknowledge the partiality in, which can make sense in understanding the real world. In operation, these principles lead to the need for recognition of multiple constructions of knowledge, and to seek, rather than try to dismiss, the key roles of ignorance, uncertainty, diversity, critical deliberation and imagination (Brown et al. 2010: 104). According to the burst detection of the literature, we found that in 2015, a highly cited paper, Head (2014), appeared, and he argued that the concept of “wicked problems” has attracted increasing focus in policy research, but the implications for public organizations have received less attention. Based on the literatures on systems thinking, collaboration and coordination, and the adaptive leadership roles of public leaders and managers, he combine the main organizational and cognitive dimensions and identify several recent approaches to addressing problem complexity and stakeholder divergence. This means that public policy researchers have realized the mono-disciplinary approach to studying wicked problems has left them little to work with, which could be an argument to adopt transdisciplinary approaches instead, which might have led to an increase of the publication output again after 2015.

4.2 The Discipline Distribution on Wicked Problems

The research discipline on wicked problems is transdisciplinary. The distribution of the top ten subject categories is presented in Table 2 below. The subject classification itself is a relatively complex issue, and different countries or regions, and even databases, have different subject classification systems. The Crown Indicator proposed by the Centre for Science and Technology Studies (CWTS) uses the JCR (Journal Citation Report) subject category as the reference standard for the standardization of paper citations. WOS use the JCR subject category to cover 252 disciplines. Considering that the research data of this article is from the WOS database, WOS subject classification and journals belong to a many-to-many relationship (Fig. 3). In other words, a journal can belong to multiple WOS subject classifications at the same time, and one WOS subject classification corresponds to several journals. Therefore, we can easily observe the transdisciplinary nature of disciplines and journals. We made statistics based on the classification of Web of Science (WOS) disciplines. Burton Clark believes in the “New Theory of Higher Education”, a discipline of two meanings: one is a “discipline” as a piece of knowledge; the other is an organization built around these “disciplines”. Because the Web of Science subject classification scheme is developed for information retrieval rather than citation analysis, we further manually integrated the WOS subject classification results by knowledge type (KT) to obtain environmental, public management, urban planning, business management, politics, education and other major categories.

Table 2 Discipline categories based on WOS & KT

Discipline category of knowledge type (KT)	Discipline category of WOS	Publications	Percentage (WOS)	Percentage (KT)
Environmental	Environmental Science	126	15.75%	44.26%
	Environmental Studies	125	15.63%	
	Ecology	51	6.38%	
	Green Sustainable Science Technology	52	6.50%	
Public management	Public Administration	101	12.63%	12.63%
Planning	Regional Urban Planning	67	8.38%	8.38%
Business management	Management	61	7.63%	13.24%
	Business	47	5.88%	
Politics	Political Science	46	5.75%	5.75%
Educational	Education Educational Research	43	5.38%	5.38%

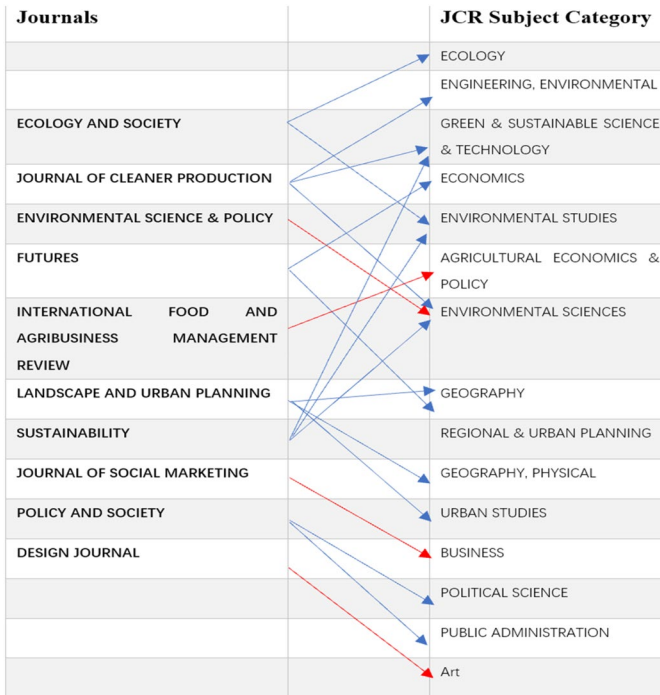


Fig. 3 The discipline classification of top 10 journals on wicked problems

There are 354 papers distributed in the environmental field, accounting for up to 44.26% of the wicked problem research. This means this field dominates the research, which is related to the increasing attention of various countries to sustainable development and environmental issues. The second subject category is business

management. There are 108 papers in total, accounting for 13.24%, which shows that wicked problems have increasingly become an important topic in the field of business management, posing a challenge to scientific managerialism. There are 101 papers in public management, which are comparable to the situation of business management. In addition, planning, political science, and education are the main subject camps that study wicked problems. Even though wicked problems have arisen in the field of planning, the attention of other disciplines to this problem has surpassed planning. Wicked problems have become important issues of multidisciplinary attention. It is also necessary to introduce wicked problems to other subject areas to promote transdisciplinarity research, like environmental sociology, environmental psychology, etc. Ramadier (2004) illustrates transdisciplinary contributions by some environmental psychologists through the study of people-environment relations in urban areas by the contributions of scholars in anthropology, architecture, history, human geography, urban sociology and psychology (Fig. 4).

According to the distribution of journals presented by the search results of “web of science”, the top ten journals that publish research related to wicked problems are: Sustainability (20), International food and agriculture management review (17), Landscape and urban planning (17), Policy and society (16), Futures (14), Environmental science policy (13), etc. According to the results of WOS’s division of journals, the corresponding maps of the top ten journals and disciplines can be obtained (see Fig. 5). We found that most journals belong to at least two disciplines. In addition, ENVIRONMENTAL SCIENCE & POLICY, INTERNATIONAL FOOD AND AGRIBUSINESS MANAGEMENT REVIEW, JOURNAL OF SOCIAL MARKETING, and DESIGN JOURNAL are more mono-disciplinary than others. But JOURNAL OF CLEANER PRODUCTION, SUSTAINABILITY, LANDSCAPE AND



Fig. 4 Discipline co-occurrence on wicked problems

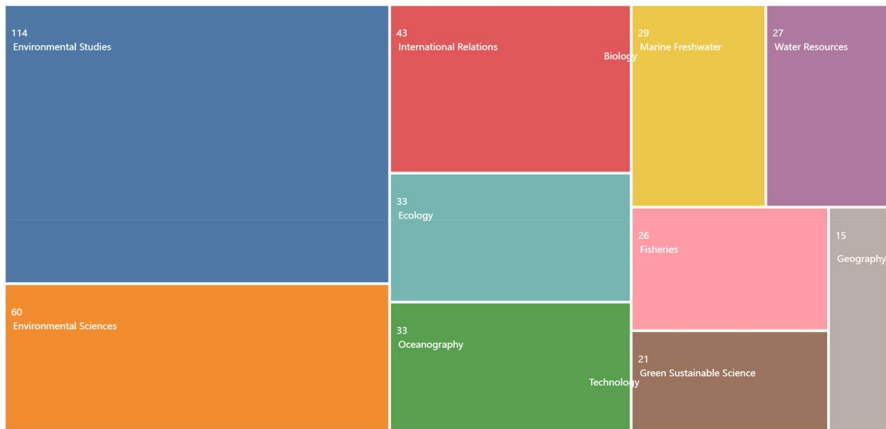


Fig. 5 Citing discipline distribution of most cited article in environmental

URBAN PLANNING are transdisciplinary journals. It shows that these important academic journals that publish wicked problems have transdisciplinary attributes.

Transdisciplinarity continuous communication, interaction, and close cooperation between researchers and research institutions in search of intellectual consistency rather than intellectual unity (Lawrence 2004). In bibliometric analysis, the process of transdisciplinary communication can be demonstrated through the co-occurrence network of papers in different disciplines, and the cooperation network between researchers in different disciplines. The flow of knowledge can reflect whether a topic has transdisciplinary attributes and its development direction of knowledge in the future. The flow of knowledge can be intensively reflected by the category attributes of the disciplines and the discipline co-occurrence. The behavior of citing papers from other disciplines by papers in a certain discipline can be regarded as a transdisciplinary research behavior in which knowledge flows from different disciplines. It is also a process of knowledge units from a single discipline or free state to reorganization to generate new knowledge.

According to the disciplines of the literature provided in the WOS data, when an article belongs to two WOS disciplines at the same time, it is regarded as a co-occurrence of disciplines. In other words, the co-occurrence map of disciplines represents the transdisciplinary network relationship of a research topic. According to the discipline co-occurrence map (see Fig. 4), the node size represents the number of citations. In the co-citation graph, there are 77 nodes, 290 connections, and the network density is 0.0991. The largest subnetwork members (environmental) have 72 nodes, accounting for 93% of the total nodes, which shows that a co-occurrence network has been formed between different disciplines studying wicked problems, and there is an inter-disciplinary mutual citation relationship. In addition, following the guiding line of citation, there are many disciplines citing articles in environment and public administration. Taking the most cited article “Fisheries and coastal governance as a wicked problem” (Jentoft and Chuenpagdee 2009) in environmental as an example, it was published in “MARINE POLICY”, which was classified as

environmental studies in WOS. This article has 275 citing documents as of September 29, 2021, and excepting environmental studies and environmental sciences, this article was also cited by international relations (43) and oceanography (33), as seen in Fig. 4. It can be proved that exporting the wicked problem concept to other disciplines like international relations has become a truth. The academia has already formed a dynamic trend of transdisciplinary knowledge flow of wicked problems. It would create more space for other disciplines to study this issue.

Citespace provides three levels of scientific cooperation networks, namely micro-level co-author, meso-level co-institution and macro-level co-country or co-territory. The transdisciplinarity co-work could be presented by collaboration networks of researchers from different disciplines. In the co-author graph, there are 39 nodes, 17 connections, and the network density is very low—only 0.0229—which indicates that there is a lack of transdisciplinary cooperation on wicked problems (Fig. 6). In addition, co-author maps can remind us that wicked problems should be introduced from the fields of management, behavioral science, agronomy, environmental science. It is beneficial to introduce academic resources and carry out transdisciplinary cooperation. From the perspective of the largest cooperative group, Domenico Dentoni from Management Studies Group, Wageningen University cooperated with Verena Bitzer (Graduate School of Business, University of Cape Town, South Africa); R. Brent Rossb (Department of Agricultural, Food and Resource Economics, 317B Agriculture Hall); Greetje (Partnerships Resource Centre, Rotterdam School of Management, Erasmus University); Steve Waddell (Lead, Ecosystems Labs, GOLDEN, Boston, Massachusetts, USA); and Milla McLachlan (Food Security Initiative, Stellenbosch University), respectively, and conducted transdisciplinary research on wicked problems. They used transdisciplinary knowledge to explain what wicked problems are, why they are wicked and how to deal with them. But overall, the space of transdisciplinary collaboration on wicked problems needs to be explored and expanded (Fig. 6).

4.3 Knowledge Development Trajectory: From Knowledge Diffusion (Mono-discipline) to Knowledge Unity (Interdisciplinarity) and Then to Knowledge Coherence (Transdisciplinarity)

The ranking table of keyword centrality (see Table 3) and the network map of keyword co-occurrence (see Fig. 7) can be further obtained through keyword co-occurrence analysis. The keyword frequency analysis method is to extract keywords that can express the core content of the document, and use the frequency distribution of keywords to study the development trends and research hotspots of the field. Keyword co-occurrence analysis uses the common occurrence of keywords or noun phrases to determine the relationship between the topics represented by the document collection. Generally, the more keywords that appear in the same article, the closer the relationship is between the two topics. Therefore, keyword co-occurrence analysis can show hot content, topic distribution and knowledge structure of a research topic. In a set of documents, according to the frequency of the keywords appearing in the same document, a keyword co-occurrence network can be formed,

Springer Nature

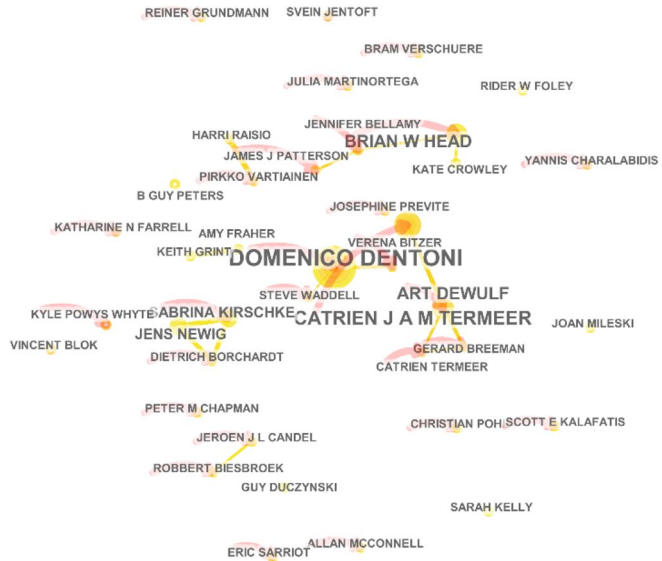


Fig. 6 Co-author map on wicked problems

Table 3 Keyword centrality ranking list

Keywords	Centrality	Year	Keywords	Centrality	Year
Volcanic risk	0.23	2019	Transdisciplinary approach	0.08	2015
Sustainable development	0.17	2012	Resilience	0.08	2012
Public participation	0.15	2012	The wicked problem	0.07	2012
Framework	0.15	2012	Wicked nature	0.07	2013
Management	0.12	2009	Public policy	0.07	2010
Communication	0.12	2015	Food security	0.07	2012
Transdisciplinarity	0.11	2015	System	0.06	2009
Social science	0.11	2018	Social problem	0.06	2015
Governance	0.09	2008	Performance	0.06	2013
Conservation	0.09	2011	Collaboration	0.06	2010

and the distance of the network nodes can reflect the closeness of different topics. Secondly, key centrality statistics can reflect the research hotspot of a certain topic. The higher the centrality of the keyword, the hotter the research topic. Thirdly, based on the guiding line and background data, the knowledge structure and development trajectories could be further concluded.

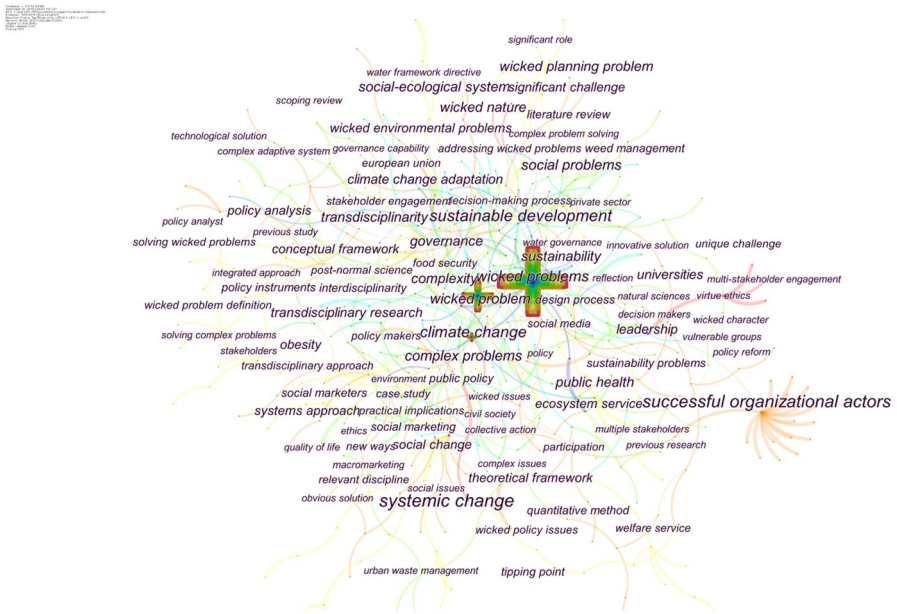


Fig. 7 Keyword co-occurrence map

From the ranking table of centrality, the top ten keywords are Volcanic risk (0.23), Sustainable development (0.17), Public participation (0.15), Management (0.12), Communication (0.12), Transdisciplinarity (0.11), Social science (0.11), Governance (0.09), as well as Conservation (0.09). Centrality is an indicator that measures the importance of nodes in the network. We found that the more cross-border issues or issues involving transdisciplinary knowledge were displayed, the higher the centrality. In addition, the proposition of transdisciplinary research on wicked problems first appeared in 2015, with a centrality of 0.11. Table 3 shows that wicked problems appear in environmental governance, sustainable development, public administration, and other fields like volcanic risk, sustainable development, governance, etc., which have already been discussed as a transdisciplinarity issue. The main coping methods of wicked problems are public participation, communication, transdisciplinarity, conservation, etc.

This study found that the concept of wicked problems has the highest frequency and is closely connected with other keywords. Also, a tight co-occurrence network map of wicked problems is presented. A research field generally goes through the initial concept formation stage, and with the emergence of a large number of research tools, the ability and scope of research begin to increase. Then, it enters the diffusion stage, in which researchers apply this research method to other disciplines beyond the original research problem. Finally, a research field will enter the attenuation phase (Shneider 2009). According to the keyword co-occurrence map, this paper explores the path of wicked problem research from knowledge diffusion (mono-discipline) to knowledge coherence (transdisciplinarity).

To begin, as mentioned earlier, the concept of wicked problems originates from the planning field, which advocates engineering technology problems and social problems dichotomy. In the research on wicked problems, disciplinary and professional boundaries are being broken, and it has gone beyond the scope of mono-disciplinary knowledge and formed transdisciplinary research, like environmental sociology and environmental psychology. Now, the transdisciplinarity epistemology for wicked problems is bred, which integrates professional knowledge into political science, economics, policy science, management, ecology, planning, biology, and other disciplines (Berkes and Folke 2000; Lang et al. 2012).

On the one hand, transdisciplinarity research on wicked problems represents the entry of the post-normal science era. Because the transdisciplinarity approach follows the principle of the integration of multiple stakeholders in the knowledge production process, in addition to specialist scientific knowledge, the results are a final knowledge that is anticipated to be greater than the sum of disciplinary components (Lawrence and Després 2004; Tress et al. 2004; Mobjörk 2010). On the other hand, the transdisciplinarity research trend also reflects that wicked problems are actually political issues, and occasionally are in the political spotlight, and may even generate sustained, intractable political controversies (Shön and Rein 1994). For example, volcanic risk is not only an environmental issue, but also an issue of global public policy. It will cause a series of social problems, which commonly involves the political intentions of different parties, tensions, and mismatches between spatial and temporal scales relating to environmental change. In addition, solutions for wicked problems are evolving from taming methods of mono-disciplinarity to coping and governance strategies, which promote the inclusive knowledge production of transdisciplinarity and develop diversified or open-ended solutions.

Under the traditional analytical paradigm of rationality-science, first-generation research was carried out by a certain discipline and saw wicked problems as a distinct and identifiable subject. The solutions proposed were often unsatisfactory due to the limitations of professional knowledge. Ambitious policy makers may even get frustrated by wicked problems because they keep trying to solve problems that are perhaps unsolvable (Termeer et al. 2015). Most scholars argue that the cognitive perspective of the problem determines the “optimal solutions” to deal with wicked problems, and the complex and dynamic nature of wicked problems requires a flexible decision-making process (Reed 2008; Sutherland et al. 2012).

Moving to the second generation of research, with more and more interconnection between different disciplines, most scholars proposed that wickedness is related to the wicked problem itself. Most scholars have called for understanding, accepting, and utilizing the complexity and uncertainty of wicked problems. It is impossible to define “one size fits all” solutions because of wickedness about the present and future environmental conditions and intractable differences in social values (Shindler and Cramer 1999). Some scholars argued that policy makers ought to take transdisciplinarity approaches into consideration when addressing wicked problems. It is more systematic than other approaches and narrows the gap between the world and our ways of thinking. Then coping solutions on wicked problems are promoted, such as focusing on stakeholder perception, emphasizing policy learning, transdisciplinarity knowledge management, transdisciplinarity research collaboration, and

adaptive management (Ackermann and Williams 2002; Hoppe 2009; Hunter 2007; Weber and Khademian 2008; Sachs et al. 2010; Head and Alford 2015). These solutions are revising the traditional linear decision-making process and scientific paradigms of public policy. Furthermore, it is necessary to promote experts from different disciplines and practitioners to form a collaborative team or establish a scientific community to seek integration. These strategies will help to achieve the aims of the barrier-free flow of information, facilitate the sharing of power and knowledge among partners, and create public value in the resolution process (Talwar et al. 2011).

4.4 Transdisciplinary Research Trend on Wicked Problems

Citation analysis is the basis of document co-citation and coupling analysis. In bibliometrics, citation analysis is a method of comparison, induction, abstraction, and generalization using mathematical and statistical methods. It is an information measurement method that analyzes the citation and citation phenomenon of scientific journals, papers, researchers and other analytical objects to reveal their quantitative characteristics and internal laws. Due to the objective existence of citation behavior and the continuous advancement of scientific research, the co-citation network will be formed naturally. First, the density of the co-citation network can reflect the dispersion and concentration of citation distribution. Secondly, the citation network between documents can trace the source forward and trace the development backward, reflecting the law of knowledge development of a certain topic, and reflecting the accumulation, continuity and inheritance of scientific knowledge. Finally, the co-citation network can reflect the intersection, penetration, and integration relationships between disciplines. The citation network can be displayed through co-citation analysis, which means that if two documents appear in the reference list of the third citing document, the two documents form a co-citation relationship. Secondly, through the cluster analysis of co-citation, we can further observe the number of documents in different clusters. The more documents in the cluster, the more important the research field is, as represented by the cluster. Thirdly, through co-citation timeline view, clustering documents can be placed on the same horizontal line, and through the time span of the documents, the rise, prosperity, and decline of a particular cluster research can be obtained.

The literature co-citation map on wicked problems is presented in Fig. 8. The term “source” includes title, abstract, author keywords (DE) and keywords plus (ID). The node type is based on cited reference and the cosine algorithm is used to calculate the correlation strength of literature links. In the threshold setting, the top fifty cited papers with the highest frequency in each time slice are extracted. The LLR algorithm is used to identify the co-citation clustering. In co-citation analysis, the node size represents the number of citations. In the co-citation graph, there are 528 nodes, 2420 connections, and the network density is 0.0174, which means the research on wicked problems has a strong concentration and high degree of network overlap. The largest subnetwork members have 483 nodes, accounting for 91% of

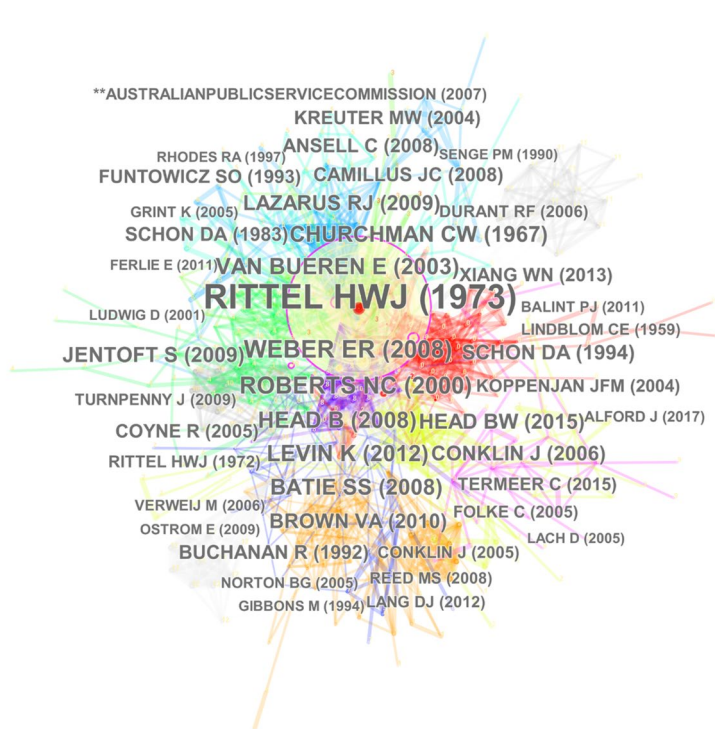


Fig. 8 Literature co-citation map

the total nodes, forming the structure diagram of origin and circle layer (see Fig. 8). The most cited article is “Dilemmas in a General Theory of Planning” (Rittel and Webber 1973), which is the origin of the first formal expression of wicked problems (see the central point in Fig. 8).

In order to clearly show the reference relationship in the time zone map, we used the burst detection method. If the citation frequency of a paper suddenly increases rapidly in the detection of sudden documents, it means that this paper hits the key issues in this academic field. Combined with cluster analysis, the network is divided into eleven co-citation clusters (see Fig. 9). These clusters are labeled by index terms from their own citers.

The largest five clusters are summarized. The largest cluster (#0) has 41 members and a silhouette value of 0.788. It is labeled as “policy integration” by LLR. The second largest cluster (#1) has 38 members and a silhouette value of 0.702. It is labeled as “interactional expertise” by LLR. The third largest cluster (#2) has 26 members and a silhouette value of 0.703. It is labeled as “governance capabilities” by LLR. The 4th largest cluster (#3) has 23 members and a silhouette value of 0.862. It is labeled as “large systems change” by LLR. The 5th largest cluster (#4) has 22 members and a silhouette value of 0.893. It is labeled as “corporate strategy” by LLR. But the cluster of the transdisciplinary research (#7) only includes 21

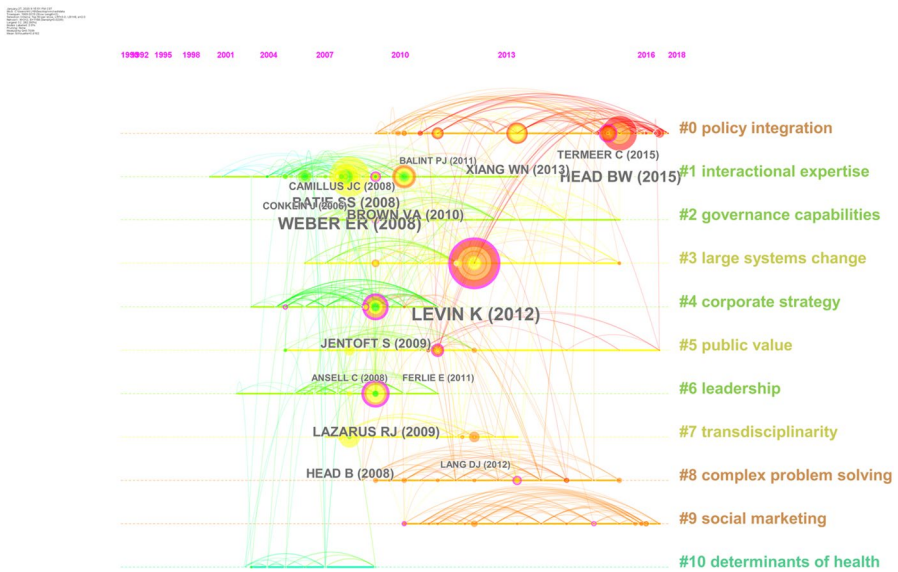


Fig. 9 Timeline view of co-citation map

documents and has a silhouette value of 0.748, indicating that there is still a lot of room for exploration of this cluster.

In addition, according to generated narratives, the most active citer to this cluster is Head (2008) “Wicked Problems in Public Policy”, with citation counts of 25, indicating that transdisciplinarity research burst in 2008. Besides, public policy issues are wicked and require the transdisciplinary approach. Beyond that, cited articles distributed in *JOURNAL OF ENVIRONMENTAL POLICY & PLANNING*, *JOURNAL OF HAPPINESS STUDIES*, *ENVIRONMENT AND PLANNING C-GOVERNMENT AND POLICY*, *FOOD SECURITY, LANDSCAPE AND URBAN PLANNING*, *IMPLEMENTATION SCIENCE*, *SOCIAL SCIENCE COMPUTER REVIEW* and other academic journals means that transdisciplinary research on public policy is being bred.

Head (2008) proposed a more comprehensive problem division framework based on the stakeholder attitudes of complexity, uncertainty, and divergence, and the problem will become wicked when all criteria reach their maximum values. Lazarus (2009) also claims that the people who are best suited to address wicked problems are not only those who caused them, but also those who have the least direct motivation to act within the shorter time frame necessary. Given the diversity in values, as actors become more aware that there are no perfect and enduring solutions to wicked problems, the alternative solution is to develop explicit approaches to knowledge-sharing among stakeholders and or decision-makers and transdisciplinary collaboration (Balint et al. 2011). Head and Xiang (2016a, b) argue that the adaptive, participatory, and transdisciplinary (APT) approach works on wicked problems and the theory and practice of incremental advancement and open systems can gain stronger support. Moreover, the transdisciplinary research teams need to attend

the investigation process of the rich contexts underlying problem scoping (Norris et al. 2016). Head (2019) argues that the “scientific” approach to social policy and planning has failed to provide reliable guidance to practitioners and researchers addressing complex and wicked social issues. In the first research generation of wicked problems, faced with the complexity and uncertainty in policy debates, differences of interest and conflicts of value of multiple stakeholders became the issues concerned, and complex and iterative approaches were generally advocated to solve wicked problems. However, the approach tends to isolate the wicked problem as a special category that requires a special collaborative process. After 40 years of development, the second generation of scholars who study wicked problems highlight the understanding and analysis of wicked problems and advocate the optimization of policy formulation and implementation process. In other words, policymakers ought to have a profound understanding of complexity and uncertainty, pay attention to the problem framing, policy design, policy capability, and policy implementation environment, etc. As mentioned earlier, one of the important signs of transdisciplinary research is accepting the local context and uncertainty.

Moreover, there is a need to strengthen the understanding of policy makers’ behaviors under backgrounds so as to make policies with creative thinking. In the field of public policy, Head (2019) thought it was time to strengthen and mainstream the analysis of wicked problems by drawing on more nuanced models of policymaking and implementation. Therefore, scholars and policymakers ought to take into account crises and contingencies in decision-making, continuously improve policy and evaluation capabilities, strengthen policy systematic collaboration capabilities, acknowledge the limitations of single-discipline knowledge, and promote policy learning and policy change. Head (2008) put forward three most effective transdisciplinary methods: promoting better integration of knowledge, promoting better stakeholder consultation, and better use of partnerships—that is, expanding the scope of consensus, treating consultation as a sustainable process, and improving the state of information exchange among stakeholders. At the same time, third-party partnerships (NGOs and companies) can help innovate service delivery ways. Under the current administrative constraints, we should step out of technical rational thinking and strengthen transdisciplinary collaborative work, establishing a new leadership style, reforming foundational government management to respond to wicked problems, and build as much consensus as possible on the problem definition and solutions to deal with it (Head and Alford 2015; Newman and Head 2017).

5 Conclusions

Wicked problems involve competition between problem definitions and preferred solutions. Science and policy are interwoven, which brings the risk of science politicization or policy technocracy (Weingart 1999). This paper reveals the current situation and development trend of transdisciplinary research on wicked problems. Firstly, the stages of wicked problems could be divided into two stages, that is, specialization and inclusive knowledge production. Currently, the research on wicked problems has entered the diffusion stage which is accompanied by the emergence of

inclusive knowledge production. Secondly, the research disciplines of wicked problems show a trend of transdisciplinarity. However, the main research discipline of wicked problems is still focused on the environment, public management and planning, while other disciplines have more room for researching wicked problems. Besides, academic journals that publish wicked problems have transdisciplinary attributes. According to the discipline co-occurrence result of wicked problems, the academia has already formed a dynamic trend of transdisciplinary knowledge flow. The paper found that natural science is more mono-disciplinary to utilize expertise in their discipline to tame wicked problems, and social science research is more transdisciplinary in its use of knowledge to deal with wicked problems. With the formation of a discipline co-occurrence network, more space would be created for other disciplines to study wicked problems, but there is a lack of transdisciplinary research teams on wicked problems. In addition, based on the keyword centrality ranking list, the more cross-border issues or issues involving transdisciplinary knowledge, the higher the centrality is. According to the keyword co-occurrence map, the research of wicked problems follows the path from knowledge diffusion (mono-disciplinarity) to knowledge coherence (transdisciplinarity). Last but not least, according to the paper's co-citation analysis, public policy issues are regarded as wicked problems, and transdisciplinary research on public policy is being bred. The discipline of public policy has the potential to change the knowledge constraints of a single discipline and may offer interdisciplinary approaches to wicked problems.

In governance theories, this paper finds that the definition of the wicked problem shows a trend of diversification. An integrated transdisciplinarity definition and solutions of wicked problems have not yet formed. The notion of wickedness has several advantages. Wickedness theory enables scholars to bring together academic, organizational, and societal concerns. The fundamental advantage of wickedness theory is that it uses a more comprehensive perspective to examine the splitting mechanisms at play, such as value divergence, institutional complexity, and cognitive uncertainty, to replace technocratic approach. It also enables scholars to revitalize age-old insights into contestation, related to notions such as multiple actors, interests, values, mutual dependencies, networks, and uncertainty (Van Bueren et al. 2003; Klijn and Koppenjan 2004; Ansell and Gash 2008). In addition, scholars tie academic debates to contemporary societal issues, such as unemployment (Baum and Mitchell 2010), health care (Ferlie et al. 2011), mental health (Hannigan and Coffey 2011), education (Bore and Wright 2009), environment, energy, and health (Turnpenny et al. 2009). However, wicked problems tend to resist clear definition and demarcation in practice and perhaps in an academic sense as well. The theoretical framework and governance mechanism are still in the process of exploration. In the future, we ought to reconsider attempts at pinning down the ultimate defining criteria of wicked problems, and to develop and use the wicked problem concept in a more analytically precise way. Considering the critiques at the long list of criteria of Rittel and Webber (1973), and building on Head (2019) and Kirschke et al. (2019), the dimensions of conflict, complexity, and uncertainty look like promising candidates for specifying wickedness. If the concept of wicked problems is defined as a transdisciplinary problem, it will contribute to the development of a transdisciplinary governance framework for wicked problems. Therefore, understanding the

transdisciplinarity characteristics of wicked problems is the most important issue for scholars to study.

The biggest academic contribution is establishing a close connection between transdisciplinarity and wicked problems as its study subject. It answers questions about transdisciplinarity research status and knowledge evolution on wicked problems, which remain under-developed in the transdisciplinarity research of wicked problems. Furthermore, the successful linking of the study of wicked problems and transdisciplinarity research has considerable potential for studies in the future. In the field of governance or public policy, contributions lie in the initiation of discipline integration and the imperative use of the transdisciplinary method of governance when dealing with wicked problems of any kind. In public policy theories, the analysis of wicked problems should be mainstreamed. While continuing to recognize the centrality of conflict, complexity, and uncertainty, and the need for creative thinking, a broader approach would make better use of such topics, such as problem framing, policy design, policy capacity, and the contexts of policy implementation. Indeed, the complexity of both the nature of the problem and the complexity of the sociopolitical context have pushed public policy theories to reconsider the rational and linear assumptions that were dominant around the time Rittel and Webber proposed their framework. Such shifts have been observable, such as focusing on deliberative and interactive forms of governance, acknowledging complex policy designs and instrument mixes (Howlett 2019), understanding processes and mechanisms of change (Capano and Howlett 2019), more nuanced forms of policy evaluation (McConnell 2010), and an uptick of debates on the “relational turn” and processual relationalism. The value of this thesis for humanities and social sciences, in particular, the transdisciplinarity approach, could play a major role in global wicked problem governance theory, enlightening researchers to study wicked problems from the perspective of system complexity and focus on knowledge connections between disciplines.

In practice, the transdisciplinary coping strategies of wicked problems have become hot recently. However, there still lacks in-depth discussion on the transdisciplinarity strategies of wicked problems. The concept of wicked problems started when Horst Rittel discussed systemic planning problems in society and summarized ten characteristics. Recent studies have proposed strategies, such as transdisciplinarity knowledge integration, networked governance, and complex adaptation. However, there still lacks exploration in the transdisciplinarity characteristics of wicked problems from an understanding perspective. The biggest problem in dealing with wicked problems has been the inability of both researchers and policy-makers to see the actual extent and nature of wicked problems. The key to the wicked problem’s solution lies in decision-makers’ recognition of the problem and prioritization of the solution. And wickedness theory suffers from a paradox: framing problems as wicked—academically, politically, or publicly—in and of itself generates obstacles for addressing wicked issues. Problems become so grand and removed from daily practice that actors are inclined to retreat instead of addressing the problems. And there is still a lack of transdisciplinary methodology. At present, the frontier research topics on the wicked problem are hybrid governance strategies, such as network governance (Van Bueren et al. 2003), collaborative governance (Roberts 2000),

adaptive governance (Gunderson and Light 2006), or interactive governance (Torfing et al. 2012). It emphasizes policy learning, effective stakeholder participation, governance capacity growth, environmental education enhancement; cognition and analysis methods; theoretical and methodical construction, and design thinking, etc. The wickedness theory states that it tends to be a holistic, or systematic approach, rather than street observations of the people and local governance practices, and tends to solve big problems rather than small ones. It offers an optimistic tone of the solution, which is an emphasis on networking, trust, and learning, seemingly having nothing to do with the roughness of the evil problems experienced by practitioners and professionals. Many wickedness theories are still quite abstract: they clarify what needs to be done, but do not clarify how to do it. It causes problems for those who have to act in the face of wicked problems.

Combining theoretical and practical research, we discover that the research scope on wicked problems is still evolving and spreading in public policy. However, the in-depth exploration of wicked problems from the perspective of transdisciplinarity is lagging behind in both epistemology and methodology which is incompatible with its complex nature. It is an inability to carry out effective policy design, and it is also difficult to formulate effective governance strategies. Restricted by disciplinary boundaries, the academic community has not reached a consensus on the concept, theoretical basis, and research use of wicked problems. It has not clarified the path of transdisciplinary knowledge evolution of wicked problems, nor formed a transdisciplinary research model. Scholars can pay more attention to the construction of transdisciplinarity systematic theory and the integration of transdisciplinarity knowledge on wicked problems in subsequent studies, specifically with the following aspects:

Firstly, new insights and knowledge on wicked problems can be generated through professional collaboration between professionals and laypeople in the future. Secondly, the transdisciplinarity interpretation theory on wicked problems should be constructed through promoting communication between different knowledge contributors, broadening the theoretical horizon, and promoting disciplinary integration and innovation. Finally, the connection between different disciplines should be strengthened. Instrumental, ethical, and aesthetic knowledge should be integrated to form a holistic science, and solutions on wicked problems should be explored from a holistic scientific perspective.

Author contribution Xiaojing Hou is responsible for writing articles, constructing analysis frameworks, data collection, data analysis, and article translation. Ruichang Li is responsible for making constructive revisions to the article, responding to reviewers, and language polishing. Zhiping Song is responsible for data analysis, article revision, article translation, and responding to reviewers.

Funding The authors declare no funding.

Availability of data and material Not applicable.

Code availability Not applicable.

Conflicts of interest Authors declares no conflict of interest

References

- Ackermann, R.T., and J.W. Williams Jr. 2002. Rational treatment choices for non-major depressions in primary care: An evidence-based review. *Journal of General Internal Medicine* 17 (4): 293–301.
- Ackoff, R.L. 1974. *Redesigning the future*. New York: Wiley.
- Alford, J., and B.W. Head. 2017. Wicked and less wicked problems: A typology and a contingency framework. *Policy and Society* 36 (3): 397–413.
- Allen, J.H. 2013. The wicked problem of chemicals policy: Opportunities for innovation. *Journal of Environmental Studies and Sciences* 3 (2): 101–108.
- Ansell, C., and A. Gash. 2008. Collaborative governance in theory and practice. *Journal of public administration research and theory* 18 (4): 543–571.
- Balint, P.J., R.E. Stewart, A. Desai, and L.C. Walters. 2011. *Wicked environmental problems: Managing uncertainty and conflict*. Washington, DC: Island Press.
- Batie, S.S. 2008. Wicked problems and applied economics. *Agricultural and Applied Economics Association* 5: 1176–1191.
- Baum, S., and W.F. Mitchell. 2010. Labour underutilisation and gender: Unemployment versus hidden-unemployment. *Population Research and Policy Review* 29 (2): 233–248.
- Berkes, F., and C. Folke. 2000. *Linking sociological and ecological systems: Management practices and social mechanisms for building resilience*. New York: Cambridge University Press.
- Bertolini, L. 2010. Coping with the irreducible uncertainties of planning: an evolutionary approach. In *Ashgate research companion to planning theory: Conceptual challenges for spatial planning*, ed. P. Healey and J. Hillier. Aldershot: Ashgate.
- Bevir, M., and R.A. Rhodes. 2006. Interpretive approaches to British government and politics. *British Politics* 1 (1): 84–112.
- Bore, A., and N. Wright. 2009. The wicked and complex in education: Developing a transdisciplinary perspective for policy formulation, implementation and professional practice. *Journal of Education for Teaching* 35 (3): 241–256.
- Brown, V.A., J.A. Harris, and J.Y. Russell, eds. 2010. *Tackling wicked problems through the transdisciplinary imagination*. London, Washington, DC: Earthscan.
- Camillus, J.C. 2008. Strategy as a wicked problem. *Harvard Business Review* 86 (5): 98.
- Capano, G., M. Howlett, M. Ramesh, and A. Virani. (Eds.). 2019. *Making policies work: First-and second-order mechanisms in policy design*. Edward Elgar Publishing.
- Carroll, M.S., K.A. Blatner, P.J. Cohn, and T. Morgan. 2007. Managing fire danger in the forests of the US inland northwest: A classic “the wicked problem” in public land policy. *Journal of Forestry* 105 (5): 239–244.
- Chen, C., Y. Chen, X. Wang, Z. Hu, and H. Hou. 2003. *Mapping scientific frontiers: The quest for knowledge visualization*. New York: Springer-Verlag.
- Churchman, C.W. 1967. Free for all. *Management Science* 14 (4): 141–146.
- Conklin, J. 2006a. *Dialogue mapping. Building shared understanding of wicked problems*. West Sussex: Wiley.
- Conklin, J. 2006b. *Wicked problems & social complexity*. San Francisco: CogNexus Institute.
- Coyne, R. 2005. Wicked problems revisited. *Design Studies* 26 (1): 5–17.
- Crowley, K., and B.W. Head. 2017. The enduring challenge of ‘wicked problems’: Revisiting Rittel and Webber. *Policy Sciences* 50 (4): 539–547.
- Daviter, F. 2017. Coping, taming or solving: alternative approaches to the governance of wicked problems. *Policy Studies* 38 (6): 571–588.
- Dépelteau, F. 2008. Relational thinking: A critique of co-deterministic theories of structure and agency. *Sociological Theory* 26 (1): 51–73.
- Farrell, R., and C. Hooker. 2013. Design, science and wicked problems. *Design Studies* 34 (6): 681–705.
- Ferlie, E., L. Fitzgerald, G. McGivern, S. Dopson, and C. Bennett. 2011. Public policy networks and ‘wicked problems’: A nascent solution? *Public Administration* 89 (2): 307–324.
- Fiksel, J. 2003. Designing resilient, sustainable systems. *Environmental Science & Technology* 37 (23): 5330–5339.
- Fischer, F. 1993. Citizen participation and the democratization of policy expertise: From theoretical inquiry to practical cases. *Policy Sciences* 26 (3): 165–187.
- Gibson, C.A., and M. Tarrant. 2010. A ‘conceptual models’ approach to organisational resilience. *Australian Journal of Emergency Management* 25 (2): 6–12.

- Grant, M.J., and A. Booth. 2009. A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal* 26 (2): 91–108.
- Gunderson, L., and S.S. Light. 2006. Adaptive management and adaptive governance in the everglades ecosystem. *Policy Sciences* 39 (4): 323–334.
- Hannigan, B., and M. Coffey. 2011. Where the wicked problems are: the case of mental health. *Health policy* 101 (3): 220–227.
- Head, B.W. 2008. Wicked problems in public policy. *Public Policy* 3 (2): 101.
- Head, B.W. 2014. Evidence, uncertainty, and wicked problems in climate change decision making in Australia. *Environment and Planning C: Government and Policy* 32 (4): 663–679.
- Head, B.W. 2019. Forty years of wicked problems literature: Forging closer links to policy studies. *Policy and Society* 38 (2): 180–197.
- Head, B.W., and J. Alford. 2015. Wicked problems: Implications for public policy and management. *Administration & Society* 47 (6): 711–739.
- Head, B.W., and W.N. Xiang. 2016a. Why is an APT approach to wicked problems important? *Landscape and Urban Planning* 154: 4–7.
- Head, B.W., and W.N. Xiang. 2016b. Working with wicked problems in socio-ecological systems: More awareness, greater acceptance, and better adaptation. *Landscape and Urban Planning* 154: 1–3.
- Hendriks, P. 1999. Why share knowledge? The influence of ICT on the motivation for knowledge sharing. *Knowledge and Process Management* 6 (2): 91–100.
- Holton, R.J. 2007. Global networks. Macmillan International Higher Education.
- Hoppe, R. 2009. Scientific advice and public policy: Expert advisers' and policymakers' discourses on boundary work. *Poiesis & Praxis* 6 (3–4): 235–263.
- Horlick-Jones, T., and J. Sime. 2004. Living on the border: Knowledge, risk and transdisciplinarity. *Futures* 36 (4): 441–456.
- Howlett, M. 2019. Designing public policies: Principles and instruments. Routledge.
- Hunter, B. 2007. Conspicuous compassion and wicked problems: The Howard government's national emergency in Indigenous affairs. *Agenda: A Journal of Policy Analysis and Reform* 14 (3): 35–51.
- Innes, J.E., and D.E. Booher. 1999. Consensus building and complex adaptive systems: A framework for evaluating collaborative planning. *Journal of the American planning association* 65 (4): 412–423.
- Jentoft, S., and R. Chuenpagdee. 2009. Fisheries and coastal governance as the wicked problem. *Marine Policy* 33 (4): 553–560.
- Jones, B.D., and F.R. Baumgartner. 2005. A model of choice for public policy. *Journal of Public Administration Research and Theory* 15 (3): 325–351.
- Kirschke, S., A.D. Häger, Kirschke, and J. Völker. 2019. Agricultural nitrogen pollution of freshwater in Germany. The governance of sustaining a complex problem. *Water* 11 (12): 2450.
- Klijin, E.-H., and I. Snellen. 2009. Complexity theory and public administration: A critical appraisal. In *Managing complex governance systems*, ed. G. Teisman, A. van Buuren, and L. Gerrits, 87–104. London: Routledge.
- Koppenjan, J.F.M., J. Koppenjan, and E.H. Klijin. 2004. *Managing uncertainties in networks: A network approach to problem solving and decision making*. London: Routledge, Psychology Press.
- Lang, D.J., A. Wiek, M. Bergmann, M. Stauffacher, P. Martens, P. Moll, M. Swilling, and C.J. Thomas. 2012. Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science* 7 (1): 25–43.
- Lawrence, R.J. 2004. Housing and health: From interdisciplinary principles to transdisciplinary research and practice. *Futures* 36 (4): 487–502.
- Lawrence, R.J., and C. Després. 2004. Futures of transdisciplinarity. *Futures* 4 (36): 397–405.
- Lazarus, R.J. 2009. Super wicked problems and climate change: Restraining the present to liberate the future. *Cornell Law Review* 94: 1153.
- Levin, K., B. Cashore, S. Bernstein, and G. Auld. 2012. Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences* 45 (2): 123–152.
- Lönngrén, J. 2017. *Wicked problems in engineering education: Preparing future engineers to work for sustainability*. Göteborg: Chalmers University of Technology.
- Lönngrén, J., and K. Van Poeck. 2020. Wicked problems: A mapping review of the literature. *International Journal of Sustainable Development & World Ecology* 28 (6): 481–502.
- McConnell, A. 2010. Understanding policy success: Rethinking public policy. Macmillan International Higher Education.
- Mobjörk, M. 2010. Consulting versus participatory transdisciplinarity: A refined classification of transdisciplinary research. *Futures* 42 (8): 866–873.

- Newman, J., and B.W. Head. 2017. Wicked tendencies in policy problems: Rethinking the distinction between social and technical problems. *Policy and Society* 36 (3): 414–429.
- Noordegraaf, M., S. Douglas, A. Bos, and W. Klem. 2017. How to evaluate the governance of transboundary problems? Assessing a national counterterrorism strategy. *Evaluation* 23 (4): 389–406.
- Noordegraaf, M., S. Douglas, K. Geuijen, and M. Van Der Steen. 2019. Weaknesses of wickedness: A critical perspective on wickedness theory. *Policy and Society* 38 (2): 278–297.
- Norris, P.E., M. O'Rourke, A.S. Mayer, and K.E. Halvorsen. 2016. Managing the wicked problem of transdisciplinary team formation in socio-ecological systems. *Landscape and Urban Planning* 154: 115–122.
- Peters, B.G. 2015. *Pursuing horizontal management: The politics of public sector coordination*. Lawrence: University Press of Kansas.
- Ramadier, T. 2004. Transdisciplinarity and its challenges: The case of urban studies. *Futures* 36 (4): 423–439.
- Reed, M.S. 2008. Stakeholder participation for environmental management: A literature review. *Biological Conservation* 141 (10): 2417–2431.
- Renn, O. 2008. *Risk governance: Coping with uncertainty in a complex world*. London, Sterling: Earthscan.
- Rittel, H.W., and M.M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4 (2): 155–169.
- Roberts, N. 2000. Wicked problems and network approaches to resolution. *International Public Management Review* 1 (1): 1–19.
- Roe, E. 2013. *Making the most of mess: reliability and policy in today's management challenges*. Duke University Press.
- Sabel, C. F., and J. Zeitlin. 2012. Experimentalist governance. *The Oxford handbook of governance* 1: 2–4.
- Sachs, S., E. Rühl, and C. Meier. 2010. Stakeholder governance as a response to wicked issues. *Journal of Business Ethics* 96 (1): 57–64.
- Selg, P., B. Klasche, and J. Nögesto. 2021. Wicked problems and sociology: Building a missing bridge through processual relationalism. *International Review of Sociology*. <https://doi.org/10.1080/03906701.2022.2035909>.
- Shindler, B., and L.A. Cramer. 1999. Shifting public values for forest management: Making sense of wicked problems. *Western Journal of Applied Forestry* 14 (1): 28–34.
- Shneider, A.M. 2009. Four stages of a scientific discipline; four types of scientist. *Trends in Biochemical Sciences* 34 (5): 217–223.
- Shön, D.A., and M. Rein. 1994. *Frame reflection: Toward the resolution of intractable policy controversies*. New York: Basic Books.
- Simon, H.A. 1962. The architecture of complexity. *Proceedings of the American Philosophical Society* 106 (6): 467–482.
- Small, H., and B.C. Griffith. 1974. The structure of scientific literatures I: Identifying and graphing specialties. *Social Studies of Science* 4: 17–40.
- Somerville, M.A., and D. Rapport, eds. 2002. *Transdisciplinarity: Recreating integrated knowledge*. London: McGill-Queen's Press-MQUP.
- Sutherland, L.A., R.J. Burton, J. Ingram, K. Blackstock, B. Slee, and N. Gotts. 2012. Triggering change: Towards a conceptualisation of major change processes in farm decision-making. *Journal of Environmental Management* 104: 142–151.
- Talwar, S., A. Wiek, and J. Robinson. 2011. User engagement in sustainability research. *Science and Public Policy* 38 (5): 379–390.
- Termeer, C.J., A. Dewulf, G. Breeman, and S.J. Stiller. 2015. Governance capabilities for dealing wisely with wicked problems. *Administration & Society* 47 (6): 680–710.
- Thompson Klein, J. 2004. Prospects for transdisciplinarity. *Futures* 36 (4): 515–526.
- Torfing, J., B.G. Peters, J. Pierre, and E. Sørensen. 2012. *Interactive governance: Advancing the paradigm*. oxford university Press on demand.
- Tress, G., B. Tress, and G. Fry. 2004. Clarifying integrative research concepts in landscape ecology. *Landscape Ecology* 20: 479–493.
- Turnbull, N., and R. Hoppe. 2019. Problematizing 'wickedness': A critique of wicked problems concept, from philosophy to practice. *Policy and Society* 38 (2): 315–337.
- Turnpenny, J., I. Lorenzoni, and M. Jones. 2009. Noisy and definitely not normal: responding to wicked issues in the environment, energy and health. *Environmental Science & Policy* 12(3): 347–358.
- Turok, I., 2014. The resilience of South African cities a decade after local democracy. *Environment and Planning A* 46: 749–769.

- Van Bueren, E.M., E.H. Klijn, and J.F. Koppenjan. 2003. Dealing with wicked problems in networks: Analyzing an environmental debate from a network perspective. *Journal of Public Administration Research and Theory* 13 (2): 193–212.
- Verweij, M., M. Douglas, R. Ellis, C. Engel, F. Hendriks, S. Lohmann, S. Ney, S. Rayner, and M. Thompson. 2006. Clumsy solutions for a complex world: The case of climate change. *Public Administration* 84 (4): 817–843.
- Weber, E.P., and A.M. Khademian. 2008. Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. *Public Administration Review* 68 (2): 334–349.
- Weingart, P. 1999. Scientific expertise and political accountability: Paradoxes of science in politics. *Science and Public Policy* 26 (3): 151–161.
- WHO. 1946. Preamble to the Constitution of the World Health Organization. WHO, New York, USA.
- Xiang, W.N. 2013. Working with wicked problems in socio-ecological systems: Awareness, acceptance, and adaptation. *Landscape and Urban Planning* (110): 1–4.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Xiaoqing Hou is a Ph.D candidate at the School of International Relations and Public Affairs, Fudan University. Her research interests include cross-border governance, digital government, and emergency management.

Ruichang Li is a professor, doctoral supervisor, and head of the Department of Public Administration at the School of International Relations and Public Affairs, Fudan University. His main research interests are emergency management, public administration and intergovernmental relations.

Zhiping Song is a Ph.D candidate at the School of International Relations and Public Affairs, Fudan University. His research interest is public policy analysis.