Concept for an Open Data Ecosystem to Build a Powerful Data Environment

Larisa Hrustek[1]([✉]) [iD], Renata Mekovec[1] [iD], and Charalampos Alexopolus[2] [iD]

[1] Faculty of Organization and Informatics, University of Zagreb, Pavlinska 2, Varazdin, Croatia
`lhrustek@foi.unizg.hr`
[2] Department of Information and Communications Systems Engineering, University of the Aegean, 83200 Karlovassi, Samos, Greece

Abstract. Today, data is seen as the starting point for change and innovation in business and management processes. Since the goal of an open data ecosystem is for stakeholders to actively create and use data, their needs must be clearly identified and defined. An analysis of the ecosystem's key elements, characteristics, and modes of operation is required to create an environment that efficiently harnesses the full potential in the creation, use, and reuse of data. This paper proposes an approach for developing a conceptual model of the open data ecosystem in a given environment based on the identified key elements and their characteristics. The following key elements of the open data ecosystem are: Stakeholders, Data, Infrastructure, and Policy/Governance. The identified elements require detailed engagement and elaboration within the open data ecosystem. By clearly identifying these elements, a strong and resilient open data ecosystem can be analyzed and built in any industry such as agriculture, transport, education, law, finance and other potential field or specific field in the public sector, contributing to long-term growth and development.

Keywords: Ecosystem Approach · Open Data Ecosystem · Elements · Open Data

1 Introduction

Open data provided an opportunity to establish a participatory society, develop innovative data-based solutions, discover new business opportunities and make better decisions in the public and private sectors [1]. Data is considered a driver of change and innovation in governance and business processes, but the realization of its potential requires building and functioning in a targeted environment called an ecosystem. The ecosystem in a broader sense represents a system in which entities work in collaboration and interdependently, as well as strive to contribute to the ecosystem [2]. In a narrow sense, an ecosystem is an environment with its own specificities and includes stakeholders who contribute to the ecosystem by sharing resources, knowledge and skills, striving to achieve social and business goals. In many domains, the value potential of data is recognized and consequently increasingly dominate by interdependent services and data

exchange between different stakeholders, which leads to the emergence of data ecosystems [3]. Different research has been conducted in the open data management field, but knowledge about data ecosystem management and its operation is limited [1, 4, 5], specifically in the various professional field. Nevertheless, the creation, use and reuse of data [1] are necessary for the successful construction and development of a data-driven culture, as one of the strategically important directions in the growing data economy according to European strategy for data [6]. Accordingly, there is a need to research data ecosystems, that is, to identify the key elements, characteristics and ways how to successfully achieve principles that such a system should satisfy. In this research, an ecosystem approach was applied and it was analyzed how the ecosystem elements contribute to the realization of this approach principles. In this paper, the research questions (RQ) are defined as a following:

RQ1: What are the elements of the (open) data ecosystem?
RQ2: What characteristics should the (open) data ecosystem satisfy for the purpose of successful operations?
RQ3: Which identified elements of the (open) data ecosystem have an impact on the realization of the principles of the ecosystem approach?

The contribution of this research stems from the need to create circular data ecosystems and strengthen specific data environments. A circular data ecosystem presents an environment where stakeholders together contribute to building a common field where they operate in a way that shares their own data and uses data from others, they know data needs and upgrade data flows. To create an environment that successfully leverages its full potential in the creation, use, and reuse of data, an analysis of the ecosystem's key elements, characteristics, and modes of operation are essential.

The following part provides an explanation of the ecosystem approach used in this research, a description of the problems observed, and the research design. The third part of the paper provides a literature review with an analysis of the results of existing research. The fourth part provides a presentation of the results, while the fifth part provides a discussion and suggestions for further research.

2   Research Approach and Design

2.1   The Ecosystem Approach

Originally, the ecosystem approach implies a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable manner [7–9]. This approach seeks to achieve a balance in conservation, sustainable use as well as a fair and equitable sharing of the benefits arising from the use of resources [7–10]. First, this approach came to settle down in natural science such as biological and environmental science, while later it found useful application in different sciences such as information science. The ecosystem approach has become a guide through various theoretical, conceptual and practical aspects of complex systems relevant to socio-ecological management [11]. Each complex system with its own specific, elements, characteristics and objectives are called an ecosystem. An ecosystem is defined as

a system of stakeholders, practices, values and technologies in a particular environment, where the mentioned elements are connected and interdependent [12]. The literature mentions 12 principles (P) on which the ecosystem approach is based. They are shortly mentioned as follow: The management objectives of resources are a matter of societal choice (P1), Decentralized management to the lowest appropriate level (P2), Ecosystem managers should consider their effects (P3), Recognizing potential gains from management (P4), Conservation of ecosystem structure and functioning (P5), Ecosystems must be managed within the limits of their functioning (P6), The ecosystem approach should be undertaken at the appropriate spatial and temporal scales (P7), Long-term objectives for ecosystem management (P8), Management must recognize that change is inevitable (P9), Balance between, and integration of, conservation and use of biological diversity (P10), Processes based on information, including scientific and indigenous and local knowledge, innovations and practices (P11), Involvement of all relevant stakeholders (P12) [7, 9, 13]. The operation of the ecosystem based on these principles is significant for the development of a sustainable and strengthened environment, as, for example, a data ecosystem should be. Essential elements and characteristics of some ecosystem contribute to the realization of these principles. The application of the ecosystem approach is necessary for the analysis of the elements and characteristics of a specific ecosystem, as well as the achievability of the principle.

2.2 Research Problem and Motivation

According to the ecosystem approach, dependence on other parties is necessary for the strategic management and operation of the ecosystem. Governance institutions, which have largely been initiators and promotors of open data initiatives, have launched open data portals, and are increasingly dependent on other organizations that produce high-quality data. Data management in such organizations is becoming increasingly critical. In addition to existing research on data management within organizations, data management in the ecosystem is more difficult to understand and very limited is known about it [4]. Despite the great interest in the data ecosystem, clear definitions are lacking [1]. The information and data flow between different stakeholders are obscure and their roles are not clearly defined [1, 5]. The publication and exchange of data in the private sector are encouraged [6], but the significant needs for different types of valuable government and private data remain superficial and incomprehensible [1]. The impact of open data in specific sectors of public governance has not yet been deeply understood and assessed [1], as well as initiatives at the level of data ecosystems are missing. Also, it is discussed a lot of issues and concludes that there is a paradox that open data (publication need) potential is decreased due to the provision of already enhanced (well-developed) e-commerce and e-government services [14]. Therefore, the observed problems can be classified in a narrow and broad sense.

Several problems were identified in a narrow sense of the data ecosystem:

- unclear definition of a data ecosystem;
- the lack of a sound identification of the key elements of the data ecosystem and limited knowledge of its characteristics;

- the relationship confusion and unclear data flow between the stakeholders of the ecosystem;
- lack of focus on developing and building the data ecosystem in practice;
- lack of data management knowledge and skills of those involved in the data ecosystem.

In a broader sense, the mentioned problems are reflected in the limited growth and development of the open data field which causes the following problems:

- lack of use and reuse of open data
- questionable sustainability of open data initiatives.

2.3   Research Design

The study was divided into two parts. The first part of the research focused on determining the answers to RQ1 and RQ2. The second part of the research provided an overview of the connection of elements to the principles of the ecosystem approach and provided an answer to RQ3.

For the first part of the research, based on the ecosystem approach, the guideline for reporting systematic reviews Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was applied. PRISMA guidelines enable the implementation of research through the identification of relevant literature in three phases: Identification, Screening and Included. Papers from the relevant databases in the investigated research field Web of Science (WoS) and Scopus were included in the investigation process. The
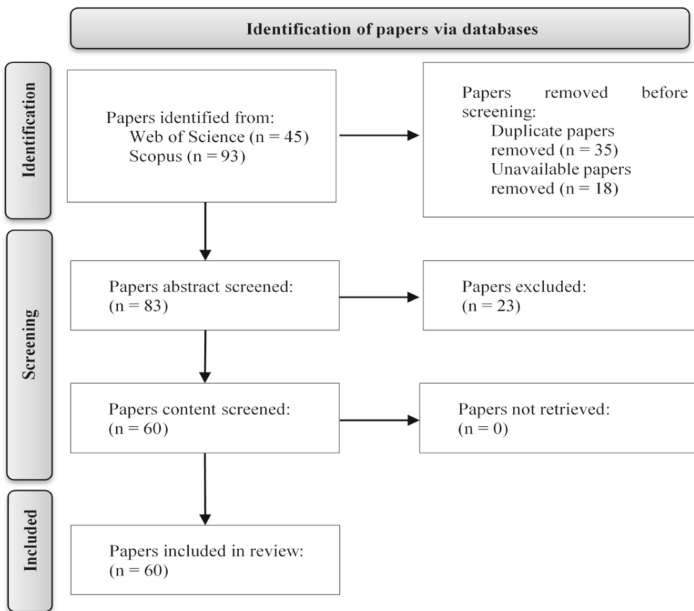

Fig. 1. Preferred Reporting Items in research

complex query in the research was: "data ecosystem" OR "open data ecosystem" AND "elements" OR "components".

In the Identification phase (Fig. 1), a list of papers from WoS and Scopus was gathered based on a complex query, and duplicate as well as unavailable papers were removed. In the Screening phase, an analysis of abstracts was made, and papers whose thematically did not correspond to the researched field were excluded from the research. Secondly, papers whose content corresponds to the selected research topic were subjected to a detailed analysis. Focus in literature analysis is placed on papers that deal with the topic of "data ecosystem" or "open data ecosystem", and which in the content include an analysis of the elements or components of the data ecosystem, as well as the characteristics, prerequisites or principles of the ecosystem. The Included phase represents the total number of papers included in the results of this research.

3   Literature Review

With the development of appropriate technologies and digital society, data has become a tradable and valuable resource [15]. The establishment of industrial open data ecosystems is still in its infancy with many unknowns and unmapped in how they should be built and operate [16]. Challenges and ambiguity in all their key elements, the development of data ecosystems represent an obstacle [16] and require a research effort in defining the approach. An open data ecosystem is an environment of stakeholders who can mutually exchange, produce and consume data and its provide conditions for the creation, management and maintenance of data exchange initiatives [15]. The conditions that the data ecosystem should satisfy include the multidimensional nature of different perspectives such as economic, technical, operational, legal, social, political and institutional perspectives [15–18].

The previous literature individually deals with the research of different constructs of data ecosystems. Stakeholders in the data ecosystem are mentioned as one of the most important constructs [1, 19–22]. They can simultaneously be producers and/or users of data with different roles in the data ecosystem. The activities they carry out take place under different conditions [15]. The next more significant construct is the technologies, standards and tools used in the data ecosystem [22–24]. They enable networking in the ecosystem, actions on data and visualization of the data environment [25, 26]. Data, as a purposeful resource in the ecosystem, is the construct around which the most significant activities of the data ecosystem are made [27]. Policy/Governance is responsible for defining policies, guidelines and dissemination of data use and reuse activities [4, 28, 29]. Also, their role is significant in providing the infrastructure and support law perspective in data initiatives, such as control of data publishing obligations and rights as well as care of General Data Protection Regulation (GDPR). The concluding reflection points to a set of heterogeneous, dynamic and evolving constructs in the landscape of the data ecosystem [15].

3.1   Open Data Ecosystem Elements

The open data ecosystem is an environment that gathers stakeholders at multiple levels [18, 21, 30, 31] and infrastructurally supports all processes related to data [25, 32],

which are key resources for creating diverse values in society [30]. The purpose of a data ecosystem is to actively create and use data by stakeholders, therefore their needs should be clearly identified and defined. Stakeholders must know each other's needs in order to be able to contribute to the common goal in the ecosystem such as sharing resources (data), providing support (upgrading of skills and knowledge, infrastructure support), and creating innovations (development of new products, the innovation culture). The ecosystem can be shown through the basic elements and their characteristics with certain contextual conditions that must be met for its process and technological functioning. Key elements of the open data ecosystem are:

1. Stakeholders
2. Infrastructure
3. Data
4. Policy/Governance.

In the literature analysis, emergent entities of the data ecosystem were identified. Entities are identified as elements of the data ecosystem without which it cannot operate. A total of 60 articles were analyzed and the mentioned entities that were partially or completely subject to the treatment of the topic were extracted. One of the most frequently mentioned entities is infrastructure or various infrastructure capacities. As many as 50 articles mention different infrastructure capacities as a significant element in the data ecosystem. Furthermore, 39 articles mentioned stakeholders as an element that is indispensable for the operating of the data ecosystem due to the roles that they, as actors, occupy in the system. The data are highlighted in 38 articles and they are the subject resource of the data ecosystem. Policy/Governance is important for regulatory purposes and is marked in 24 articles.

3.1.1 Stakeholders

Stakeholders in the ecosystem, in addition to their primary goal, such as achieving some business result, have an obligation to support and contribute to the development of the data ecosystem [18, 32]. In the open data ecosystem, the contribution of stakeholders is noticeable through active participation, dynamic interaction, support of open data initiatives and the development of a data-based innovation culture in the sector [33]. Open data ecosystems are developed through the adaptation of stakeholders, their feedback loops and dynamic interaction, and the strengthening of other interdependent factors [18]. This process is supported by the proposal of the triple helix model [31]. The inclusion of all stakeholders in the process of knowledge sharing and innovation creation makes this model useful for ecosystem analysis. In one of the studies, the quintuple helix model was presented, which unites all the stakeholders of the observed ecosystem [31]. The same approach is necessary to identify stakeholders that share the same or similar problems, collaborate with similar partners, and have similar needs [34, 35]. To create a sustainable open data environment in a sector, the roles and data needs must be understood [30, 36]. Typical roles of stakeholders in the open data ecosystem are data providers, infrastructure providers, application developers, support service providers, end-users [21].

3.1.2 Infrastructure

To enable the proper functioning of all processes and an accessible environment to stakeholders, a complex infrastructure is essential in the background of the open data ecosystem [3, 24, 37]. The technical and technological infrastructure includes programs, tools, services, and data preparation activities [18]. The background activities, such as the development and implementation of programs and tools in the ecosystem, aim to make data available to users on portals or platforms [24]. The infrastructure supports the preparation of the data and its publication in an appropriate form, while the users on the portal or platform should find the data very easily and download it for use, which requires a user-friendly interface, appropriate visualization, and support service [18, 38].

Several activities characterize the importance of this element in the ecosystem. First, (a) the infrastructure for preparing and publishing open data on the Internet is important, (b) cleaning, analyzing, enriching, combining, linking, and visualizing data, (c) searching, finding, accessing, browsing, and evaluating metadata, (d) discussing data and providing feedback to the data provider and other stakeholders [16, 18]. These activities cover a wide range of topics that are critical to the development of the open data ecosystem. Some of them are data audit, dataset selection, address and map data, privacy, licensing, high quality publishing, data access, data discovery, supporting public agencies, engaging data users, promoting reuse, and evaluation [25, 39]. The open data ecosystem requires significant infrastructure capacity and a commitment to improving it in order to build an organized, functioning, and sustainable system.

3.1.3 Data

Data is a product of a data ecosystem. Fundamental processes in the data ecosystem are based on and with data, from the generation and collection of data to its availability in the ecosystem [40]. Data in the ecosystem should be easily discoverable, available and known to stakeholders, accessible for download and application, and usable for an operational purpose that provides benefits [41, 42]. The characteristics of datasets can be evaluated based on parameters such as legal, practical, technical, and social aspects [43]. Legal parameters include a machine-readable rights statement, a clear rights statement, licensing and privacy issues. Practical parameters include web accessibility, guaranteed timeliness of data, and quality issues. Technical parameters include appropriate formats and open standards. Social parameters relate to metadata, providing feedback, and promoting data. Open data can be viewed in a variety of ways, and there are several definitions. Rather than provide another formal definition, we prefer to look at the characteristics of what makes data truly open. Finally, the characteristics of data could be included and related to the conceptual model in the following ways: (a) data must be complete, (b) data must be primary, (c) data must be timely, (d) data must be accessible, (e) data must be machine-processable and posted online in a permanent archive, (f) access must be nondiscriminatory, (g) data formats must be non-proprietary, (h) data licensing must be unrestricted and have no usage costs, and (i) data should be as accurate as possible [44].

3.1.4   Policy/Governance

Policy/Governance is an element that determines the progress and development direction of data ecosystem initiatives [4, 45]. First, establishing sustainable and strong data ecosystems requires defining policies at the national level and developing them at lower, sectoral levels [2, 17, 46]. Government efforts should focus on promoting better information sharing in the public and private sectors, supporting open innovation for co-creation of products and services through budgeting and infrastructure, and actively engaging in interoperation within the data ecosystem [47, 48].

3.2   Open Data Ecosystem Characteristics

The success of the data ecosystem depends largely on the collaboration and communication among stakeholders and their joint interaction. A collaborative environment is important for creating a good climate in the environment and for sharing data knowledge and skills [12, 18]. Infrastructural capacities can be enhanced by sharing technological resources. Certainly, it is necessary to research good practices and analyze what kind of infrastructure is desirable in an ecosystem where multiple stakeholders with different needs operate. Infrastructure capacities should be interoperable and stakeholders should be familiar with their functional features. In the ecosystem, it should be outlined what kind of data is desirable and in what form it is acceptable for further use and reuse, therefore certain rules regarding data should be defined. The data ecosystem should be characterized by a culture of experimentation with data. For an open data ecosystem in a certain industry or sector, it is important to build a development strategy and development models at the management and governance levels. Attempts to develop potential products or services can improve business processes within organizations or contribute to the development of socially useful solutions [42, 47, 49, 50].

4   Open Data Ecosystem Conceptualization

The conceptual model of the open data ecosystem (Fig. 2) is presented in terms of the four elements of the data ecosystem and their characteristics to be considered in the detailed elaboration and analysis of specific ecosystems.

Stakeholders in the data ecosystem are important for several reasons. In addition to their primary role in the industry, they also have specific roles in the data ecosystem. They may be data creators or data users, or they may take on other roles. In addition, it is important to identify their potential for creating data, i.e., what useful data they create for other stakeholders in their organization. Identifying data needs, i.e., determining potentially useful data for developing one's business, requires a great deal of attention.

Infrastructure is the most complex element that requires detailed elaboration because it supports all activities in the ecosystem, including activities related to data and activities between stakeholders. The technologies and techniques selected should enable the easiest possible processing and preparation of data so that they are accessible to stakeholders for use and further processing [24]. The data ecosystem should be a secure environment for stakeholders that supports user-friendly features such as a collaborative platform, APIs, licenses, standards, tools and more [24, 51, 52].

Data is a resource that stakeholders in the ecosystem care about. It should be available in an acceptable format and meet certain characteristics and quality standards to be used for an appropriate business or societal purpose.

Policy/Governance is an element that includes the industry as a data ecosystem in the national open data policy. In addition, detailed elaboration at a lower level is desirable. Initiatives should be a priority of government institutions through supporting activities [4, 53, 54].
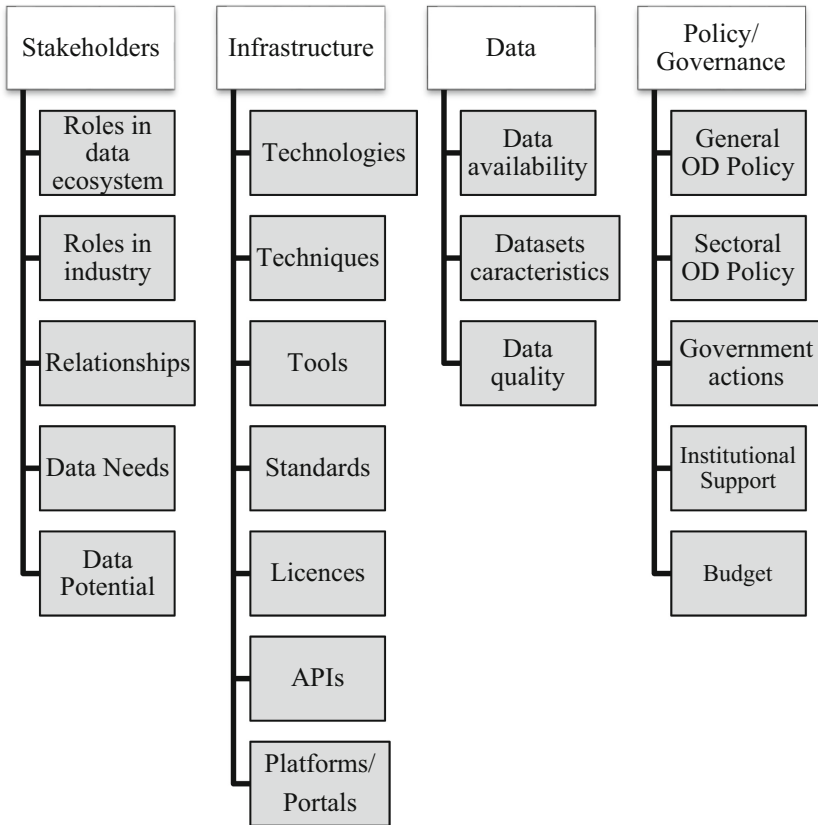

Fig. 2. Conceptual Model of Open Data Ecosystem Elements and Characteristics

Proposed elements of open data ecosystem can be explained from perspective of specific sector or a specific industry. For example, stakeholder analysis will explain how to identify roles in the sector and data environment and the potential they have in the creating and using data. In addition, infrastructure element will assess the accessibility and interoperability of technological solutions and principles. Element called data will include identification of what data are available, its quality, and its potential for use in the sector. Element Governance/Policy identify the potential of such an ecosystem and whether government or leading initiatives aim to build and financially support an

ecosystem. Future work will include the improvement of proposed model to assess the state of a specific data ecosystem and development of framework. The improvement and framework will be based on the proposed conceptual model in order to assess the identified elements of the data ecosystem. Future research will aim to assess the status of the data ecosystem of individual industries and benchmark at the level of different countries. The data ecosystem should contribute to the fulfillment of the principles of the ecosystem approach through the mentioned elements. Stakeholders are closely related to principles P3, P4, P10, P11 and P12. Infrastructure contributes to the fulfillment of principles P5, P6, P7 and P8. Data covers several principles, namely P6, P7, P8 and P11. Policy/Governance covers most of the principles, namely P1, P2, P3, P6, P7, P8 and P9.

5 Discussion and Future Work

Some issues were discovered during the study project to examine open data ecosystems in a specific sector and industry, which motivated the need for this research. Recognizing the potential, a number of projects have been started to advance the field of open data. Despite all efforts, determining how much contribution has been made and the amount to which stakeholders in a given open data ecosystem have profited is extremely challenging. As a result, open data use and reuse have not grown as they should, and future plans for the sustainability of open data programs are uncertain. To address this, our concept focuses on developing open data ecosystems within the context of a certain sector or industry. The study proposes a model for creating a powerful data environment, which covers stakeholder analysis, infrastructure challenges, data, and governance/policy considerations. Each of the aforementioned elements demands future research to elaborate on and carefully study its properties in the context of a certain sector or industry. Open data knowledge and skills are required for stakeholders to identify and fulfil their responsibilities in the data ecosystem as creators or users. A multidisciplinary approach by stakeholders can support in the creation of a stronger and more sustainable data ecosystem. The most critical issue right now is infrastructural capability. They require investments, a high-quality strategic approach, an overview of the ecosystem, and the operationalization of all ecosystem parts. National data policies continue to exclude the development of sectoral data demands and the objective of creating sector-based ecosystems.

6 Conclusion

Development-oriented open data efforts should be aligned, created, and operationalized as an ecosystem at the sector or industry level so that actual progress can be evaluated. Existing research frequently mentions the open data ecosystem, but rarely in the context of a sector or industry. These results are not surprising considering the research's complexity, which necessitates industry expertise and abilities connected to the characteristics of the open data ecosystem.

The open data ecosystem is an environment in which stakeholders with different responsibilities but similar interests operate, share, and use specific data, that is enabled by interoperable infrastructure solutions. To create a specialized open data ecosystem,

it is required to concentrate on promoting and strengthening a data-driven economy, as well as sharing open data through the deployment and availability of appropriate support technologies. The purpose of data ecosystem development proposed on this paper is to shift stakeholders' roles from passively informed actors to active co-producers of ecosystem services. Future research will concentrate on developing a framework for assessing open data ecosystems based on the proposed conceptual model, which includes important characteristic elements.

References

1. Shah, S.I.H., Peristeras, V., Magnisalis, I.: Government (big) data ecosystem: definition, classification of actors, and their roles. Int. J. Comput. Inf. Eng. **14**(4), 102–114 (2020)
2. Yunita, A., Santoso, H.B., Hasibuan, Z.A.: Everything is data: towards one big data ecosystem using multiple sources of data on higher education in Indonesia. J Big Data **9**(1), 91 (2022)
3. Rebstadt, J., Kortum, H., Hagen, S., Thomas, O.: Towards a transparency-oriented and integrating service registry for the smart living ecosystem. Informatik, Germany (2021)
4. van Donge, W., Bharosa, N., Janssen, M.F.W.H.A.: Data-driven government: cross-case comparison of data stewardship in data ecosystems. Gov. Inf. Q. **39**(2), 101642 (2022)
5. Booth, P., Navarrete, T., Ogundipe, A.: Museum open data ecosystems: a comparative study. J. Doc. **78**(4), 761–779 (2021)
6. European Commision, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A European strategy for data. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=159307 3685620&uri=CELEX%3A52020DC0066. Accessed 10 Sept 2022
7. Secretariat of the Convention on Biological Diversity, The Ecosystem Approach. https://www.cbd.int/ecosystem/#:~:text=The%20ecosystem%20approach%20is%20a,three%20objectives%20of%20the%20Convention. Accessed 09 Sept 2022
8. Ecosystems Knowledge Network. https://ecosystemsknowledge.net/ecosystem_approach. Accessed 09 Sept 2022
9. Shepherd, G.: The ecosystem approach: five steps to implementation. IUCN (2004). https://www.iucn.org/resources/publication/ecosystem-approach-five-steps-implementation. Accessed 09 Sept 2022
10. Waltner-Toews, D., Kay, J., Lister, N.-M.: The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability, Illustrated Columbia University Press, New York (2008)
11. Lister, N.-M., Waltner-Toews, D., Kay, J.: The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability (2008)
12. van Loenen, B., et al.: Towards value-creating and sustainable open data ecosystems: a comparative case study and a research agenda. JeDEM – eJ. eDemocr. Open Govern. **13**(2), Art. no. 2 (2021)
13. Shepherd, G.: The Ecosystem Approach: Learning from Experience. IUCN (2008)
14. Kassen, M.: Open data and e-government – related or competing ecosystems: a paradox of open government and promise of civic engagement in Estonia. Inf. Technol. Dev. **25**(3), 552–578 (2019)

15. Oliveira, M.I.S., Lóscio, B.F.: What is a data ecosystem? In: Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, New York, NY, USA, pp. 1–9 (2018)
16. Diran, D., Hoppe, T., Ubacht, J., Slob, A., Blok, K.: A data ecosystem for data-driven thermal energy transition: reflection on current practice and suggestions for re-design. Energies **13**(2), Art. no. 2 (2020)
17. Gupta, A., Panagiotopoulos, P., Bowen, F.: An orchestration approach to smart city data ecosystems. Technol. Forecast. Soc. Chang. **153**, 119929 (2020)
18. Zuiderwijk, A., Janssen, M., Davis, C.: Innovation with open data: essential elements of open data ecosystems. Inf. Polity **19**, 17–33 (2014)
19. Hayashi, T., Ishimura, G., Ohsawa, Y.: Structural characteristics of stakeholder relationships and value chain network in data exchange ecosystem. IEEE Access **9**, 52266–52276 (2021)
20. Moreno, J., Serrano, M., Fernández, E., Fernández-Medina, E.: Improving incident response in big data ecosystems by using blockchain technologies. Appl. Sci. **10**, 724 (2020)
21. Kitsios, F., Papachristos, N., Kamariotou, M.: Business models for open data ecosystem: challenges and motivations for entrepreneurship and innovation. In: IEEE 19th Conference on Business Informatics (CBI), vol. 01, pp. 398–407 (2017)
22. Immonen, A., Palviainen, M., Ovaska, E.: Requirements of an open data based business ecosystem. IEEE Access **2**, 88–103 (2014)
23. Osorio-Sanabria, M.A., Amaya-Fernández, F., González-Zabala, M.: Exploring the components of open data ecosystems: a systematic mapping study. In: Proceedings of the 10th Euro-American Conference on Telematics and Information Systems, New York, NY, USA, pp. 1–6 (2020)
24. Pinto, V., Parreiras, F.: Towards a taxonomy for big data technological ecosystem. In: Proceedings of the 22nd International Conference on Enterprise Information Systems, Prague, Czech Republic, pp. 294–305 (2020)
25. Lee, D.: Building an open data ecosystem - an irish experience. In: ACM International Conference Proceeding Series, pp. 351–360 (2014)
26. Alexopoulos, C., Loukis, E., Charalabidis, Y.: A platform for closing the open data feedback loop based on web2.0 functionality. JeDEM – eJ. eDemocr. Open Govern. **6**(1), Art. no. 1 (2014)
27. Janev, V.: Ecosystem of big data. In: Janev, V., Graux, D., Jabeen, H., Sallinger, E. (eds.) Knowledge Graphs and Big Data Processing. LNCS, vol. 12072, pp. 3–19. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-53199-7_1
28. Koers, H., Bangert, D., Hermans, E., van Horik, R., de Jong, M., Mokrane, M.: Recommendations for services in a FAIR data ecosystem. Patterns **1**(5), 100058 (2020)
29. Sanaei, M., Taslimi, M., AbdolhoseinZadeh, M., Khani, M.H.: A study and analysis of the open government data ecosystem models. Iran. J. Inf. Process. Manage. **34**, 609–636 (2019)
30. Lindman, J., Kinnari, T., Rossi, M.: Business roles in the emerging open-data ecosystem. IEEE Softw. **33**(5), 54–59 (2016)
31. Kitsios, F., Kamariotou, M., Grigoroudis, E.: Digital entrepreneurship services evolution: analysis of quadruple and quintuple helix innovation models for open data ecosystems. Sustainability **13**(21), Art. no. 21 (2021)
32. Runeson, P., Olsson, T., Linåker, J.: Open data ecosystems - an empirical investigation into an emerging industry collaboration concept. J. Syst. Softw. **182**, 111088 (2021)
33. Rudmark, D., Andersson, M.: Feedback loops in open data ecosystems. IEEE Softw. **39**(1), 43–47 (2022)
34. Hrustek, L., et al.: Towards digital innovation: stakeholder interactions in agricultural data ecosystem in Croatia. Interdiscip. Descr. Complex Syst. **20**(2), 190–209 (2022)

35. Hrustek, L., Tomičić Furjan, M., Šalamon, D., Varga, F., Džidić, A., von Loenen, B.: Overview of the open data agricultural ecosystem in Croatia. In: Book of abstracts of the National Open Data Conference (2021). https://www.bib.irb.hr/1148032. Accessed 14 Oct 2022

36. Kassen, M.: Adopting and managing open data: stakeholder perspectives, challenges and policy recommendations. Aslib J. Inf. Manage. **70**(5), 518–537 (2018)

37. Pires, F.M., León Quiñonez, L., de Souza Mendes, L.: A cloud-based system architecture for advanced metering in smart cities. In: 2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), pp. 1087–1091 (2019)

38. Demchenko, Y., de Laat, C., Membrey, P.: Defining architecture components of the big data ecosystem. In: 2014 International Conference on Collaboration, Technologies and Systems (CTS), pp. 104–112 (2014)

39. Luo, W.: Enterprise data economy: a hadoop-driven model and strategy. In: 2013 IEEE International Conference on Big Data, pp. 65–70 (2013)

40. Zeleti, F.A., Ojo, A.: Capability development in open data-driven organizations. In: Ojo, A., Millard, J. (eds.) Government 3.0 – Next Generation Government Technology Infrastructure and Services. PAIT, vol. 32, pp. 135–171. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-63743-3_6

41. Welle Donker, F., van Loenen, B.: How to assess the success of the open data ecosystem? Int. J. Digit. Earth **10**(3), 284–306 (2017)

42. Benitez-Paez, F., Comber, A., Trilles, S., Huerta, J.: Creating a conceptual framework to improve the re-usability of open geographic data in cities. Trans. GIS **22**(3), 806–822 (2018)

43. ODI Open Data Certificate. https://certificates.theodi.org/en/. Accessed 30 Aug 2022

44. Charalabidis, Y., Zuiderwijk, A., Alexopoulos, C., Janssen, M., Lampoltshammer, T., Ferro, E.: The open data landscape: concepts, methods, tools and experiences. In: Public Administration and Information Technology, pp. 1–9 (2018)

45. Munshi, U.M.: Data science landscape: tracking the ecosystem. In: Munshi, U., Verma, N. (eds.) Data science landscape. Studies in Big Data, vol. 38, pp. 1–31. Springer, Singapore (2018). https://doi.org/10.1007/978-981-10-7515-5_1

46. Vayena, E., Gasser, U.: Strictly biomedical? Sketching the ethics of the big data ecosystem in biomedicine. **29**, 17–39, (2016)

47. Ojo, A., Curry, E., Sanaz-Ahmadi, F.:A tale of open data innovations in five smart cities, vol. 2015, p. 2335 (2015)

48. Freitas, J.A.C., Balaniuk, R., Silva, A.P.B., Silveira, V.S.: The open data ecosystem of federal government: compositions and challenges. Ciencia Inform. **47**, 110–132 (2018)

49. Shin, D.-H., Choi, M.J.: Ecological views of big data: perspectives and issues. Telemat. Inform. **32**(2), 311–320 (2015)

50. Lockwood, M.: An accessible interface layer for self-sovereign identity. Front. Blockchain **3** (2022)

51. Balaji, V., et al.: Requirements for a global data infrastructure in support of CMIP6. Geosci. Model Dev. **11**(9), 3659–3680 (2018)

52. Moreno, J., Gómez, J., Serrano, M.A., Fernandez, E.B., Fernández-Medina, E.: Application of security reference architecture to big data ecosystems in an industrial scenario. Softw. Pract. Exp. **50**(8), 1520–1538 (2020)

53. Cue, R., et al.: Data Governance in the Dairy Industry. Anim. (Basel) **11**(10), 2981 (2021)

54. Bugbee, K., et al.: Building a data ecosystem: a new data stewardship paradigm for the multi-mission algorithm and analysis platform (MAAP). In: IGARSS IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, pp. 4261–4264 (2019)