

Circular ecosystems for the management of occupational safety and health systems

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Abstract: National systems for Occupational Safety and Health (OSH) rely on a diverse range of stakeholders. Properly managing these stakeholders represents a fundamental lever for improving the overall effectiveness of the OSH systems. Although OSH requirements are managed in different ways from country to country, there are opportunities for transnational collaboration in policy development and improvement practices by leveraging their common structures. Consequently, this study aims to identify key factors that would enable effective management of the OSH stakeholders’ network in the perspective of establishing in the future an ecosystem to support daily operations and sustainability of OSH processes, with a particular focus on interventions. Given the absence of academic OSH literature with an (eco)system view, this study explored the concept of ecosystems in other fields using a systematic literature review, which focused on circular ecosystems as they were deemed appropriate to this aim. Based on the review, we identified a framework with five key elements that define distinctive features of circular ecosystems, which suit well the OSH field and its stakeholders’ network. These elements are Value, Actors, Circular activities and strategies, Data, Materials and Flows, and Governance. These results, if properly exploited, would represent a fundamental lever for the analysis of an effective OSH ecosystem. This study is exploratory, and future research may uncover additional conceptual frameworks, from contexts other than circular ecosystems, that would also be relevant to the OSH field. Overall, this preliminary investigation lays the foundation for further exploration of the OSH ecosystem’s concept that functions across nations, transcending national boundaries.

Keywords: occupational safety; occupational health; business ecosystem; circular economy; literature review.

I. BACKGROUND

The International Labour Organization (ILO) reports that around 2.2 million people die each year because of accidental injuries suffered at work or illnesses caused by work-related factors [1]. The impact on society is huge and the social cost on workers and their families is not acceptable, therefore safety and health at work represent a matter of primary importance for both public and private organizations, regardless of their size or industry [2,3]. To address this challenge, numerous standards and guidelines for Occupational Safety and Health (OSH) management systems have been developed, and many countries have adopted national strategies that integrate the management system approach [4]. Despite differences in the management of national requirements, the adoption

of global standards, such as the International Organization for Standardization (ISO) 45001:2018 standards [5], could offer opportunities for transnational collaboration to improve policies and practices. A uniform approach based on global standards would therefore allow organizations to promote greater consistency and sharing of best practices at an international level. A national OSH system can be seen as an infrastructure composed of people managing activities in different phases, which, if properly managed, represent a lever for improving the entire system. It is, therefore, crucial to understand the key players and improving their interactions becomes crucial to create an effective network of interaction [6,7].

This work aims to identify the key factors for effective stakeholder management in the field of OSH to establish a future (eco)system that supports

daily operations and sustainability of OSH processes, and more importantly, applies across nations transcending national boundaries. From now on, we will refer to the OSH ecosystem, which can be simplistically defined as an OSH system that persists over time – striving for a stable equilibrium – where actors are conscious of their role and activities to manage, and they act not only for themselves but for the well-being of the others and the system around them. However, it is rare to find in the OSH literature this system perspective, except for a few reports published by international institutions (e.g., ILO, European Occupational Safety and Health Agency (EU-OSHA)) that retain a policy perspective of OSH. Therefore, this study aims at exploring other, non-OSH, research fields with the explicit intent to investigate the available knowledge on ecosystems in other fields and seek potentially transferable concepts that would support the development of an ecosystem’s concept in the OSH field. A Systematic Literature Review (SLR) including various kinds of ecosystems has been structured for this purpose. The analysis of the literature has revealed that studies on circular ecosystems might be transposed to the OSH field because comparable dynamics have been identified. Seminal works have been selected to this end and some key elements of circular ecosystems have been identified as relevant for the investigation of the concept in the OSH field.

The following sections are structured as follows. *Section II* describes the methodology used to carry out the SLR; *Section III* presents the review of the literature; *Section IV* discusses the results by potentially showing how the circular ecosystem’s concept can be applied to the OSH field; *Section V*, finally, draws the conclusion and states future developments.

II. METHODOLOGY

According to the aim, this work investigates the concept of ecosystems in other fields by developing an SLR, which is considered a rigorous methodology to construct a solid knowledge base [8]. The systematic search was conducted following the four phases of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9] and the entire search process (i.e., identification, screening, eligibility, included) is represented in *Figure 1*.

In the identification phase, we defined the area of interest and selected keywords for the database search. Considering the extent of the topic, a preliminary analysis of the existent types of

ecosystems was conducted to select the most potentially relevant for the OSH field. Business and circular ecosystems were selected as the most promising and the seminal work of Trevisan et al. [10], combining both – business and circular – ecosystems, was used as a starting point to build the query for the SLR. Then, it was decided to add other keywords in the search including an actor’s perspective to underline the fact that ecosystems generally involve several actors that need to be managed. The Scopus database was used for the search of documents. In total, 263 items (limited to English-written documents) were identified. The initial batch of documents was screened on the title, abstract and keywords and 42 documents resulted eligible to proceed with the selection process. After reading the full text of the eligible documents, 20 documents were included in the literature review.

These 20 documents offer a wide range of insights into business and circular ecosystems, examining the topic from various perspectives. Some of these documents focus exclusively on circular ecosystems, while others combine them with other types of ecosystems, keeping the circular ecosystem as the main topic. After reading the included documents, it emerged that circular ecosystems have the potential to be transposed into the OSH field, by identifying possible touching points between the two research areas.

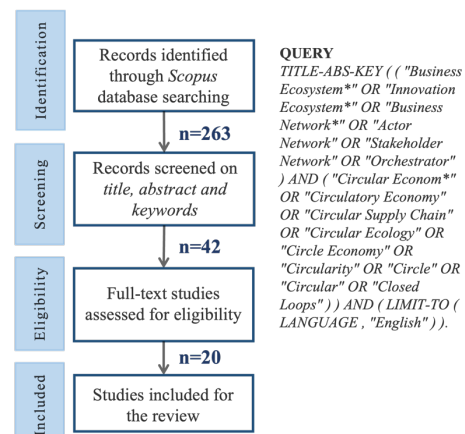


Figure 1. The search process: PRISMA flow diagram

III. LITERATURE REVIEW

The search process identified a total of 20 relevant documents to be reviewed. However, due to space constraints, this work will discuss just nine of them, which have been selected based on their potential relevance for the OSH context. The entire process of review had the intent to identify potential crucial elements of circular ecosystems that can be transposed in an OSH environment, thus facilitating

the creation of an ‘OSH ecosystem’, as defined in *Section I*.

A. Relevance of circular ecosystems

We have begun the analysis by focusing on the concept of ecosystem, which has become particularly important in understanding how linear models, ‘take, make, and waste’, can be transformed into circular ones [11]. Linear models are less efficient than circular ones due to inefficiencies in resource utilization, which mainly results from the lack of circularity in production and consumption processes [12]. Therefore, ecosystemic innovation is essential in changing how a group of actors (such as producers, consumers, waste collectors, and decomposers) collaborate and interact with each other to achieve a collective outcome [12,13].

Circular economy (CE) plays a fundamental role in this context, as it is considered a valuable approach to achieving sustainable development and creating a more resilient and efficient system [14]. The incorporation of CE concepts and principles [15] – such as systematic thinking, innovation, stewardship, collaboration, value optimization, and transparency – constitutes a complex, interconnected, and uncertain task. This requires organizations to have the ability to propose differentiated values and transform business models [16]. Therefore, the concept of circular ecosystems serves as a bridge between the literature on business ecosystems and CE.

B. Studies on circular ecosystems

The concept of circular ecosystems has been recently introduced, and the studies, presented in Table I, show key elements that can be useful to introduce the ecosystem’s concept in the OSH field. The nine documents selected for this review are summarised and key facts are underlined in Table I.

TABLE I. SELECTED DOCUMENTS IN THE LITERATURE REVIEW AND RELEVANT INFORMATION

Auth.	Documents
Aminoff et al. [17]	Exploring disruptive business model innovation for the circular economy (2017) The authors propose disruptive co-innovation of the business model as a mechanism to move from industrial systems to circular economy ecosystems. They describe the transition from value chains to overlapping value circles, where value is shared among actors through governance and innovative collaboration. The framework they suggest identifies <i>value creation innovation</i> , <i>new proposition innovation</i> , and <i>value capture innovation</i> as the three key elements for shaping industrial systems towards circular economy ecosystems.
Hsieh et al. [18]	Governing a sustainable business ecosystem in Taiwan's circular economy: The story of spring pool glass (2017)

The authors have described the creation and development of a business ecosystem for glass recycling, identifying the mechanisms employed by the company to govern it. These mechanisms include *value capture*, *stakeholder interaction*, *brand image*, *corporate social responsibility*, *company capabilities* in the recycling process and *government policy*.

Hakane n and Rajala [19]

Material intelligence as a driver for value creation in IoT-enabled business ecosystems (2018)

The authors examine the use of IoT in creating value within business ecosystems, focusing on *material intelligence* and *collaborative value creation*. They highlight the transformative potential of deploying smart materials and leveraging IoT to reshape the material lifecycle while emphasizing the value of data and enhanced traceability in improving production efficiency.

Tate et al. [12]

Seeing the forest and not the trees: Learning from nature's circular economy (2019)

The authors compared natural and corporate ecosystems based on biomimetics. The document highlights how both types of ecosystems are complex, with different actors interconnected and influential. They also point out that while natural ecosystems are based on *circular interactions between the actors*, linear industrial ecosystems have a lack of circularity in production and consumption activities. They propose adopting a circular approach to create a circular economy, balancing the roles of producers and consumers, and recognizing the importance of scavengers and decomposers.

Parida et al. [11]

Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies (2019)

This study presents a two-stage process model of ecosystem transformation to a CE, highlighting two stages: ecosystem readiness assessment and ecosystem transformation. *Ecosystem orchestrators* play a pivotal role in implementing CE principles by *coordinating transformation activities* and *fostering collaboration among ecosystem actors*. The transition to a CE brings significant economic, environmental, and social benefits, but it requires a thorough evaluation of ecosystem readiness and strategic management of the involved partners.

Konietzko et al. [13]

Circular ecosystem innovation: An initial set of principles (2020)

The study identifies three main groups of principles for circular ecosystem innovation: *collaboration*, *experimentation*, and *platformization*. Collaboration involves selecting partners, building trust, aligning interests, redefining roles and responsibilities, adopting decentralized governance, developing common strategies and goals, and ensuring fair value distribution among the involved actors. Experimentation focuses on designing value propositions, redefining resources, mapping sustainable minimal ecosystems, prototyping assets, and testing in a local experimentation space involving real customers from the early stages to develop sustainable solutions and maximize resource efficiency. Lastly, platformization involves creating a modular technological architecture, defining openness and governing data flows.

Bertassini et al. [14]

Circular Business Ecosystem Innovation: A guide for mapping stakeholders, capturing values, and finding new opportunities (2021)

According to the authors, the CE is a valuable approach for achieving sustainable development and creating a more resilient and efficient system. Transition requires a change in business models and cultural and regulatory values. To facilitate the transition to a CE, the authors propose a *four-phase guide that includes understanding the current situation*, *aligning stakeholder expectations*, *mapping existing circular values*, and *analysing opportunities*.

Trevisan et al. [10] **Unlocking the circular ecosystem concept: Evolution, current research, and future directions (2022)**
 The authors have developed a *conceptual framework for the circular ecosystem*, which is based on five key elements: *value, actors, data, materials and flows, circular activities and strategies*, and *governance*. Value plays a crucial role, involving *collective value creation and capture* with the presence of multiple value circles. Actors are interconnected and collaborate in the development and commercialization of innovations, with an orchestrator as a key figure. Data, materials, and flow management is essential, requiring a *rethinking of resource usage*, integration of data from various sources, and careful management of information and material flows. Circular activities and strategies focus on sustainability, promoting collective economic and environmental benefits. Governance supports coordination and value sharing.

Thakur and Wilson [20] **Circular innovation ecosystem: a multi-actor, multi-peripheral and multi-platform perspective (2023)**
 The authors propose an integration between CE and innovation, presenting *the circular innovation ecosystem*. The authors present a framework that includes five key components: *actors, value focus, artifacts, resource infrastructure, and choreography*. The framework highlights the important role of knowledge management and co-innovation platforms in driving innovation within the circular economy.

creation, collective value capture, and multiple circles of value [10].

A circular value proposition serves to communicate the project's objectives and the intended value to be created [13]. Value co-creation has emerged as a new approach for businesses, emphasizing interactions, shared resources, engagement platforms, and ecosystem approaches, and promoting collaboration with different stakeholders to gain a competitive advantage [17]. Ensuring effective value capture is crucial for maintaining actor commitment and ensuring timely contributions [13]. Furthermore, the circular ecosystem is characterized by multiple circles of value, where value is shared among actors through innovative governance and collaboration, reflecting the regenerative and restorative principles of a CE. Understanding collaborative dynamics that go beyond individual circles of value is crucial for a comprehensive view of the circular ecosystem [17].

IV. RESULTS AND DISCUSSION

The nine selected documents are now critically analysed and one of them, Trevisan et al. [10], is taken as a reference to structure the discussion as it proposes a conceptual framework for the circular ecosystem and identifies its core elements, which are: *value, actors, circular activities and strategies, data, materials and flows, and governance* (Figure 2). These elements serve as a model for the first characterisation of the ecosystem's concept in the OSH field, offering insights into its self-organization and value creation. Our objective is to analyse these elements, based on our SLR to explore their potential applications within the OSH context.

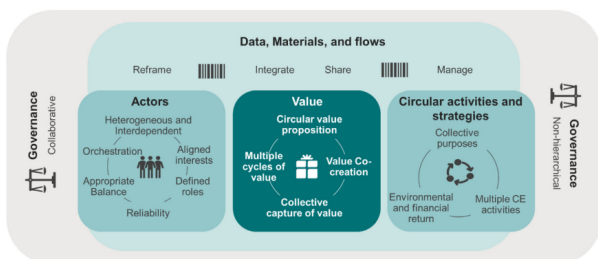


Figure 2. The circular ecosystem's framework by Trevisan et al. [10]

A. Value

The concept of value plays a crucial role in the circular ecosystem and within the OSH context. In the circular context, the value represents the benefits derived from exchanges among actors involved in the CE transition [14]. Value can be represented through *circular value proposition, value co-*

In parallel, in the OSH field, circular value proposition finds resonance in *Participatory Organizational Interventions (POI)*, which generate temporary partnerships among people involved in the research process and other interested parties with privileged knowledge and specific skills [21]. Participants are actively involved in defining goals and generating value. POIs promote collaborative co-creation of value, generating a comprehensive understanding of contextual factors influencing intervention development. Additionally, they *promote continuous and collective value capture* because the participants compare their perspectives with others, contributing to clarifying their viewpoints [22,23]. Moreover, through the collection of feedback from different actors, these interventions *promote a virtuous cycle* by producing continuous improvement in their effectiveness. Finally, POIs also *promote the creation of multiple value circles* as they enable the formation of temporary partnerships among people involved, hence fostering an environment of knowledge and sharing.

B. Actors

Actors are groups or individuals affected by or influencing organization's activities. While organizations typically focus on actors directly involved in their core business, the CE takes a systemic approach, considering the exchanges and interactions among all actors within a business ecosystem [14]. The literature over the years has

identified various characteristics regarding actors, including [10]:

Heterogeneity and appropriate balance of actors: A balanced network of diverse and complementary actors is essential for a successful transition to a circular value system. Similar to natural ecosystems, this network fosters resilience by effectively tackling challenges such as product decomposition and providing protection against external shocks [12].

Alignment of interests: Agreeing on individual and collective interests to achieve circular objectives [13].

Definition of roles and responsibilities: Participants need to have a clear understanding of their roles to avoid misunderstandings. The roles change over time and require continuous redefinition. Additionally, roles pertain to their responsibilities, which is what actors are expected to do [13].

Trust among business actors: Trust is crucial in maintaining an ecosystem's efficient coordination strategy, enabling the sharing of resources, knowledge, and innovative products. The absence of trust among actors creates a significant barrier to accepting new stakeholders [20].

These characteristics can also be applied to actors within OSH ecosystems for various reasons. The *heterogeneity of actors* involved enables leveraging diverse knowledge and skills, thus promoting a more comprehensive understanding of contextual factors that influence the development of interventions. This results in greater efficiency in designing, implementing, and evaluating OSH interventions. The *balance of actors* ensures equitable distribution of resources and efficient circularity within the OSH context. Additionally, *alignment of interests* and *mutual trust among actors* promote closer collaboration among them, facilitating the adoption of common practices and policies to improve the entire system. A clear *definition of roles and responsibilities* contributes to improving the coordination of activities within the OSH systems.

C. Circular activities and strategies

CE aims to minimize environmental impact throughout the entire production chain by implementing circular strategies in collaboration with various actors within a business ecosystem [24]. Developing *common strategies and objectives* is crucial for providing guidance to the project and enabling actors to align and identify with them. This necessitates an organized and co-creative process

[13]. Achieving circularity is a complex effort that involves multiple activities at different levels, and organizations must be prepared to navigate any turbulence that may arise [20]. It is important to emphasize that the activities implemented should be economically advantageous and environmentally sustainable to effectively support circularity. This is because the *ecosystem must generate a financial return to maintain its health*, and actors are more likely to be actively involved when the environmental impact is integrated into operational costs [10,20].

Circular strategic activities also find application in OSH, as *the approach of iterative design* fits well with the logic of participatory research [25] and enables *the integration of different stakeholders' viewpoints*. As already emphasized, aligning interests promotes closer collaboration among actors, facilitating the adoption of common practices and policies to improve safety and health at work. It is important to emphasize that the iterative process is a cyclical process that allows for continuous improvements to the entire system. As stated by Chambers et al. [26], optimizing any phase of an intervention should go through real-world testing following an iterative process of development, evaluation, and refinement in different contexts. This process enables identifying critical points and making continuous improvements to the system.

As in circular ecosystems, the implementation of circular activities in OSH should not be limited to a single sector, as this can lead to *greater collaboration and sharing of resources* among the different actors involved, fostering the creation of synergies that increase the efficiency and sustainability of the system as a whole and providing new opportunities for learning and collaboration.

In the end, as in the case of circular ecosystems, the strategies adopted in OSH must *bring economic benefits* to encourage behaviours or actions that would not otherwise take place or would develop to a minimal extent.

D. Data, Materials and Flows

Redefining and *rethinking resource utilization to maximize material circulation* is an important aspect of implementing a circular value system [13]. This entails effectively managing data to explore alternatives that facilitate material circulation. Moreover, to ensure the successful establishment of a circular value system, it is crucial to *integrate information and material flows*, ensuring precise

tracking [12]. Finally, *data sharing* is important as data flows allow for better access to information on the usage, conditions, and location of ecosystem resources, thereby contributing to more efficient management of their utilization and circularity [13]. Communication and data exchange can be facilitated through platforms that connect ecosystem actors. Platforms serve as indispensable tools for disseminating knowledge and fostering collaboration among ecosystem actors [20].

Also in the OSH field, these elements find a space: firstly, it is important to *redefine and rethink resource use* in OSH as this can improve material management efficiency and reduce the risks of occupational accidents or diseases. Therefore, the *adoption of different strategies* can contribute to more effective resource management improving the OSH context. Secondly, it is important to *integrate data from different sources* to obtain a complete view of the ecosystem.

Finally, the *sharing of resources and knowledge* is a crucial aspect of improving OSH practices. This allows organizations to access a greater number of information and tools optimizing, in this way, the use of available resources. Furthermore, it is important to emphasize that sharing knowledge is the key to pursuing positive changes. Also in this field, communication and data sharing can be facilitated using platforms that enable stakeholders to collaborate more effectively, exchange information and best practices, and have a clear overview of the OSH ecosystem.

E. Governance

Governance is a crucial component of the CE, enabling coordination and value sharing among actors. It encompasses the processes, rules, and norms through which the network enables individuals to influence operations and decision-making [17]. To ensure coordination between the essential activities that contribute to the value proposition, *ecosystem actors must adhere to predetermined rules and standards*, which may be established by *government agencies* or the *ecosystem orchestrator* [11,18]. The presence of an orchestrator is essential in implementing the principles of the CE, as this figure plays a vital role in the ecosystem by facilitating communication among actors and supporting the creation and sharing of value [11,24]. Therefore, the orchestrator *promotes cooperation and synergy*, enhancing the efficiency and effectiveness of the CE ecosystem, and contributing to its sustainable growth and development. As we mentioned before, the

transition to a CE brings significant economic, environmental, and social benefits, but it requires a thorough evaluation of ecosystem readiness and strategic management of the involved actors [11].

The governance, represented by top management, plays a crucial role in managing health and safety at work, as it coordinates the involved actors, thus improving the effectiveness of the system [27]. According to the ISO 45001:2018 standard [5], top management must demonstrate *leadership and responsibility in preventing work-related accidents and illnesses*, adopting a clear policy that reflects the organization's intentions and direction regarding OSH management. This policy must include a commitment to providing safe and healthy workplaces and activities, integrating health and safety management system requirements into business processes, promoting a safe and healthy work environment for all employees, and involving workers in consultation and participation. The individual tasked with orchestrating this process is top management, who is responsible for "directing and controlling the organization at the highest level" [5].

V. CONCLUSIONS

This study aims to identify the key factors for effective stakeholder management in the OSH context, intending to establish a future ecosystem that can be internationally applied to support daily operations and the sustainability of OSH processes. A uniform approach across nations will benefit the current OSH management, mostly characterized by local dynamics and missing a system perspective, by offering opportunities for sharing best practices at an international level and promoting greater consistency in policy and practice improvement. Therefore, considering the current absence of a system perspective in the OSH literature, this study explores the concept of the ecosystem in other research areas to investigate how the concept of an ecosystem can be introduced in the OSH field. After examining various options, the circular ecosystem emerges as the most suitable choice for this study. Based on the nine selected papers, five key elements of circular ecosystems – Value, Actors, Circular activities and strategies, Data, materials and flows, and Governance – are found to be relevant and constitute a starting point for the OSH ecosystem's definition. As proof of its relevance, this ecosystem's idea matches two ongoing Italian initiatives funded by the Italian National Institute for Insurance against Accidents at Work (INAIL). These two initiatives – 'I SHARE' (CONDIVIDO in

Italian) and 'PMP (Prevention Plans) 5.0' – despite having different scopes, both aim to establish an effective OSH ecosystem that facilitates the introduction and future management of such initiatives.

Future developments of this research will involve a more in-depth exploration of the ecosystem's characteristics. This will require consolidating the findings from the literature review and conducting exploratory analyses with international experts to study how the ecosystem can be applied in practice for daily OSH management.

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