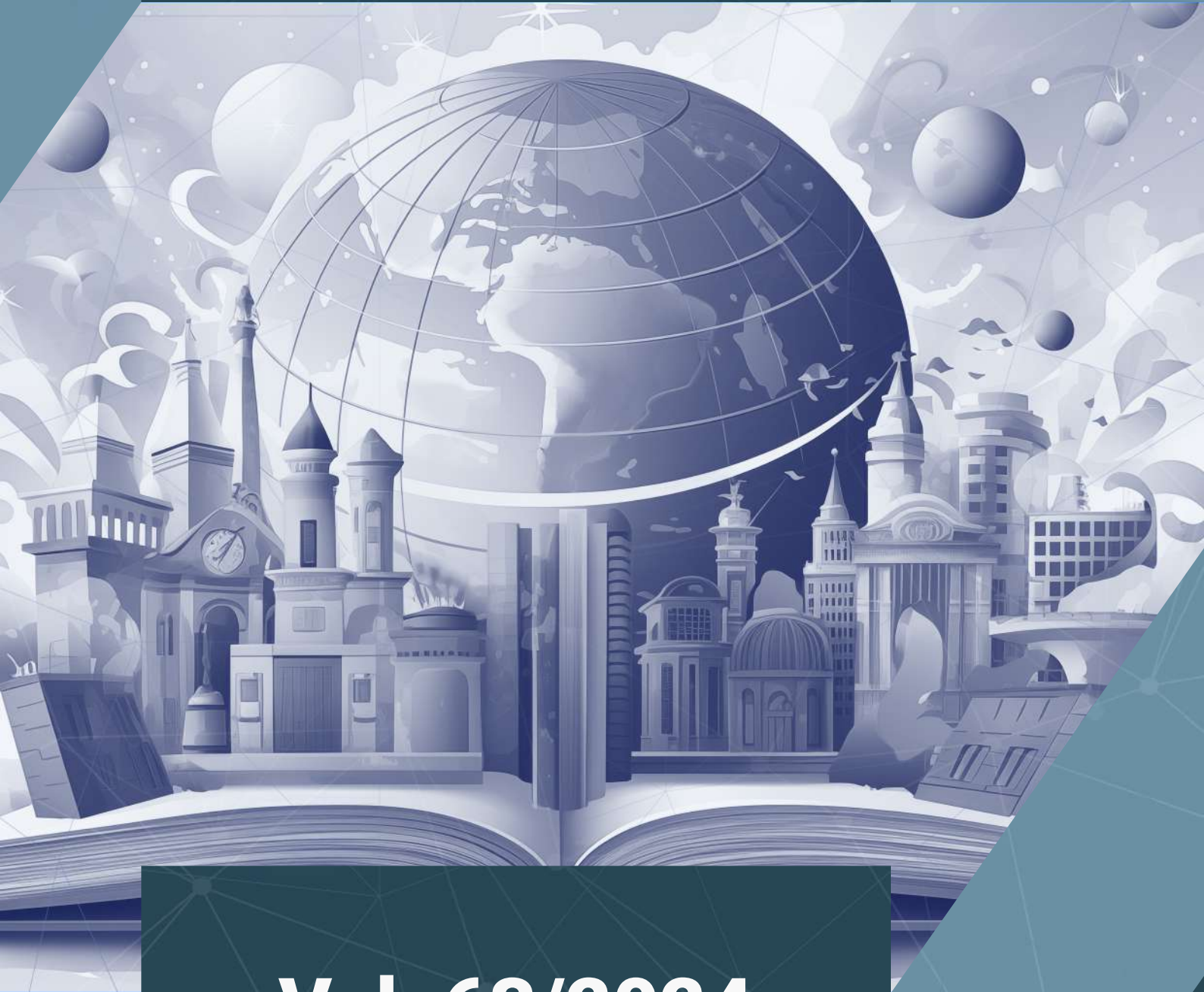




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Dynamic transnational inter-ecosystem framework for smart and inclusive age-friendly environments: The Transnational Local-Sphere Model

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Abstract. The demographic change calls for the creation of age-friendly environments that result from the collaboration between several fields. Previous initiatives fostering age-friendly environments often had less-than-desired impact or reach due to financial and bureaucratic constraints. Additionally, territory-specific standards and needs hinder the replication of good practices. Based on a mixed-methods approach combining a narrative review of knowledge models followed by expert consultation, we propose a framework to maximise the sustainability of Smart Healthy Age-friendly Environment (SHAFE) initiatives by connecting local ecosystems and stakeholders, including underrepresented entities, and thus promote sustainable business models, to ensure the replicability, scalability, and sustainability – the Transnational Local-sphere Model. This social innovation framework goes beyond previously established helix frameworks, by incorporating fresh ideas on democratic policy making, transnational spanning, and inter-ecosystem collaboration, as well as emphasising the role of institutions, stakeholders, networks, and principles. The collaboration and competition between the different stakeholders ensure a value-driven, cost-effective, and inclusive intervention, maximising impact. The Transnational Local-Sphere Model can also be applied in the development of other social innovation initiatives that benefit a user-centred multi-stakeholder inter-ecosystem approach.

Keywords. social innovation; age-friendly environments; helix framework; multi-stakeholder approach; knowledge production; innovation ecosystem

Introduction

The rapid and increasing change in our society at demographic, economic and societal levels is making smart housing solutions increasingly important to enable independent living, to ensure the continued involvement of all people in the community, regardless of their age, personal conditions, or health status, and to lessen the growing pressure on healthcare systems. However, the current housing stock is mostly unequipped to facilitate the necessary conditions for the continuously growing group of people with heterogeneous needs [1]. Consequently, there is a growing research interest in the design and implementation of age-friendly environments. In this article, we consider age-friendly environments that are responsive, inclusive, and eco-friendly; in other words, those environments that are designed or reconfigured to be more versatile, easy to enter, easy to navigate in and around, to better meet the changing needs of occupants over their lifetime, to be capable of easy and cost-effective adaptation. Moreover, we consider the environment-friendliness dimension, concerning the materials used, the energy or water consumption, and the use of local suppliers. Currently, the most common constraints to the development of age-friendly environments relate to financial and complex bureaucratic challenges, as well as ICT weaknesses [2]. There have been several initiatives aiming to promote innovation and support stakeholders to increase investments in relevant societal areas, often providing support measures to different actors such as webinars, training, and workshops. However, their impact usually runs shorter than desired in the mid- and long-term once the support services are finished [3].

The creation of age-friendly environments requires innovation on a socio-economic level, including environmental, organisational and processual changes falling thus in the realm of social innovation. *Social Innovation* (SI) concerns ‘the design and implementation of new solutions that imply conceptual, process, product, or organisational change, which ultimately aim to improve the welfare and wellbeing of individuals and communities’ [4]. *Social innovation ecosystems* are defined as environments in which social innovation emerges, although the concept is still poorly researched [5]. SI ecosystems are currently in different stages of development and are mostly territory-specific and small in scale. This can be explained by the fact that the implementation of SI ecosystems on a larger scale requires a multi-sectoral perspective, including actor-centred concepts, governance models, supportive infrastructures, and adjustment to legal and cultural norms [5]. The lack of multi-sectoral involvement was highlighted in the study of Dantas et al. on the current representation of actors in SI ecosystems, showing that ecosystems are mainly structured by universities and research centres, in collaboration with public-institutional components, with an under-representation of the private sector [3]. In this line, pilot actions within the REPLICATE project have shown that one of the challenges of creating SI ecosystems is to involve actors from the public, private and not-for-profit sectors beyond their *business-as-usual* activities [6].

Several innovation frameworks have been introduced in the past responding to the need to engage multiple stakeholders in innovation processes, such as the triple-, quadruple- and quintuple-helix frameworks [7]. Two of the pitfalls of these frameworks for the development, scalability and replicability of SI ecosystems are the lack of account for knowledge exchange and collaborations between ecosystems geographically dispersed, and for the incorporation of underrepresented entities. Particularly, socially innovative age-friendly environments, require the involvement of actors active in defending privacy preservation, social activity, affordability, and personal choice. To fill in these gaps, in this article, we introduce a new SI model, built on existing knowledge production modes and helix frameworks, that focuses on creating alliances and synergies between different stakeholders within and between ecosystems.

This research was conducted in the context of the Social Innovation Responsive Environments NETwork (SIRENE) project [8]. SIRENE aims to develop a Social Innovation framework and tools for the creation and nurturing of ecosystems in Smart Healthy Age-Friendly Environments (SHAFE). These tools can support social entrepreneurs to gain awareness on the topic and grant access to relevant networks and funding opportunities, enabling innovation investments that meet the changing needs of citizens across their lifetimes.

Methodology

A narrative review was performed to analyse the evolution of knowledge production modes and helix frameworks. The search query used contained a combination of keywords including ‘knowledge production mode’, ‘helix model’, and ‘helix framework’. A systematic review of the literature was beyond the scope of this work, though a thorough screening of the results was performed by two authors to identify relevant knowledge production modes and helix frameworks. Seventeen articles were selected for full-text analysis, including those that first described the models and/or later additions, revisions, or mentions from the same authors(s), as well as additional articles with new ideas, insights, or case-studies. Five helix models and three knowledge production modes were identified and are described in detail in the Results section.

A stakeholder consultation was performed to complement the results of the literature review in February 2023. Experts from the 27 countries of the European Union (EU-27) were identified and invited to a panel session organized within the context of the SIRENE project. Seven experts participated in a collaborative session in which the needs and gaps of responsive, inclusive eco-friendly environments were discussed using a combination of real-time polls and the Brainwriting technique [9] in a customized 7-1-1 (seven participants – one idea – one minute) format. The findings of this session were analysed by two team members and will be discussed in the results below. The questions that we posed during the session are provided in the additional material.

Results

The concept of innovation has evolved from the pioneering works of Schumpeter [10], capturing the interests of academics and practitioners, traditionally focused on economic theory, where the perspective of technological innovation is prevalent. Innovation is then seen as an engine of economic and technological growth, whereas the authors of the Linear Innovation Models, introduced in the middle of the 1980s, advocate that innovation is an invention that follows a sequence of well-defined steps, based on the assumption that innovation is applied science. In these early works, it was assumed that innovation is “linear”, where scientific research comes first, then product development, and finally production and marketing. Thus, traditional innovations have been evaluated based on economic value generation and competitive advantage [11]. However, the purpose of technological and social innovation, while related, is known to be fundamentally different [12–14]. The economic growth by itself is not a sufficient benefit of social innovation, and as a result, much work has emerged trying to build more complexity and interactions, as a new agenda related to the purpose of innovations and business in society.

Social innovation has gained attention over the past two decades driven primarily by the need to provide solutions to specific societal problems [15,16] by implementing new ideas, products, services and infrastructures adapted to the changing needs of society [17], taking place in different sectors and organisational formats, including the public sector, governments, the

non-profit sector, and also the private enterprise. In this context, several models of innovation are evolving, where new multiple-stakeholder engagement is promoted, and local and regional problems are approached toward more inclusive and sustainable solutions. First, the triple-helix model emerged to generate regional development focused on the articulation of three social agents, the academy, the industry, and the government, where the collaboration among these stakeholders was rapidly revealed as not enough. In response, the quadruple-helix model emerged, acknowledging the increasing importance of greater public participation in the innovation process, then including four actors in the model: academy, industry, government, and civil society. The quintuple-helix model defines the environment as its entity, promoting the challenge of including the social ecology concerns and innovation ecosystems, combining a wide range of expertise (social, technical, and natural sciences) and stakeholders to offer customised solutions and promote socially oriented services. Later, the penta-helix model came out, reinforcing the relevance of a multi-stakeholder approach to make innovation models more operative. More recently, the neo triple-helix framework incorporates elements of the triple-, quadruple-, and quintuple-helix frameworks providing more dynamism to the ecosystem innovation. In this section, we analyse the aforementioned knowledge production modes and helix models which can be the basis of social innovation initiatives, networks, and ecosystems.

3.1 *Knowledge Production Modes*

As the name suggests, ‘knowledge production modes’ are methodologies to produce (scientific) knowledge. Currently, three different modes have been conceptualised. Mode 1 and 2 were first described by Gibbons et al. [18]. **Mode 1** is a linear model of innovation based on traditional academic knowledge development within separated disciplines, using a hierarchical structure of established peers to ensure quality. In this mode, the acquired knowledge does not need to have any practical applications and is not guided by social needs or economic interests. **Mode 2** on the other hand, enters the realm of non-linear innovation models, which favours practical applicability, trans-disciplinarity, non-hierarchical organisation, social accountability, and reflexivity [19–21]. The mode 2 model promotes the creation of transdisciplinary collaborations, where scientists are more reflexive and use different quality standards [22]. While Gibbons et al. advocate for a shift from mode 1 to mode 2 [18], other researchers indicate that mode 2 is not a new concept and is in essence the origin of scientific research, while mode 1 is a theoretical construct and does not accurately describe the current academic model, since multi-disciplinary research and applied sciences are common elements in academia [23]. Others have accused the mode 2 framework of being a political ideology [24]. Mode 2, in the way it was described by Gibbons et al. (2010) was thus never universally accepted. Figure 1 illustrates linear and non-linear knowledge production modes.

Mode 3 was proposed by Carayannis and Campbell as a response to the increasing need for both globalising and localising (*glocalising*) innovations, and consists of innovation networks and knowledge clusters, bringing together socio-economic, political, technological, and cultural aspects, co-creating a 21st Century Innovation Ecosystem [19,25]. In mode 3 linear and non-linear innovation models are combined, building on modes 1 and 2, and the quadruple helix framework [26]. Mode 3 emphasises the co-evolution and integration of the different innovation paradigms, seeking a balance between cooperation and competition (*co-opetition*). This way a fractal knowledge and innovation ecosystem is created that is better equipped to handle modern societal problems by ‘being endowed with mutually complementary and reinforcing as well as dynamically co-evolving, co-specialising and co-operating, diverse and

heterogeneous configurations of knowledge creation, diffusion and use' (E. G. Carayannis and Campbell 2009, 223 [19]).

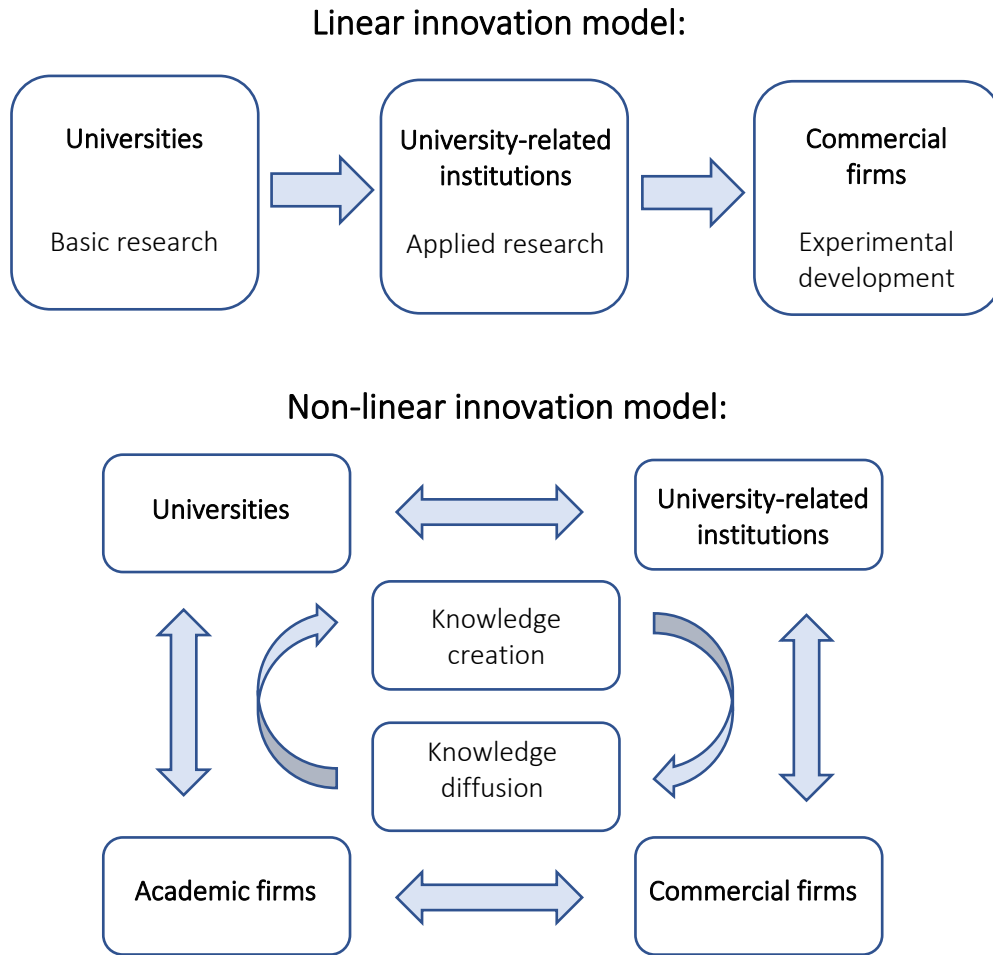


Fig. 1. Representation of linear and non-linear innovation models (adapted from E. G. Carayannis and Campbell 2009 [19]).

3.2 Helix Frameworks

3.2.1 The Triple-helix Framework

The triple-helix innovation model shown in Figure 2 was first described by Etzkowitz and Leydesdorff (1995) consisting of three overlapping institutional spheres, symbolising the government, academia, and industry. The overlapping regions represent hybrid organisations, like university spin-off firms, government laboratories, and tri-lateral initiatives for knowledge-based economic development. The authors argue that as opposed to models consisting of three separate spheres or the governmental sphere encompassing the other two, the triple-helix overlay model (also named Triple Helix III) allows for the existence of an innovative environment that is encouraged, but not controlled, by the government [23]. The model builds on the knowledge production mode 2, by forming a framework for institutional interconnections. The triple-helix model therefore enables the shift of scientific knowledge and innovation production from mode 1 to mode 2. The triple-helix model is widely adopted by policymakers around the world, which has transformed the involved sectors and allowed for the emergence of hybrid organisations and social development [28].

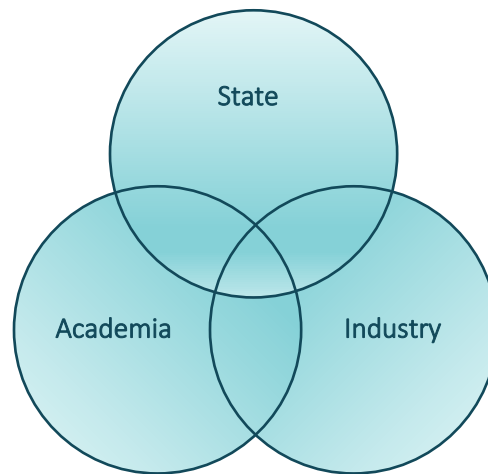


Fig. 2. The Triple-helix overlay model (adapted from Etzkowitz and Leydesdorff 2000 [23]).

The Quadruple-helix Framework

3.2.2 *The Quadruple-helix Framework*

In 2009 Carayannis and Campbell suggested adding a fourth helix to the framework – ‘media-based and culture-based public’ originating the Quadruple-helix framework illustrated in Figure 3 [19]. The fourth helix was conceptualised to emphasize the role of culture and media on innovation systems and their likelihood to succeed. Especially in recent years the influence of the media and the opinion of the public on political communication has increased. The fourth helix therefore incorporates this so-called ‘media-based democracy’, where legitimation and justification of innovation ideas by the public are part of the innovation ecosystem. The fourth helix, also sometimes referred to as ‘civil society’, covers concepts like ‘culture’, ‘value’, ‘lifestyle’, ‘art’, and ‘creative industries’ [20]. The quadruple-helix framework enables the shift of knowledge and innovation production from mode 2 to mode 3 [29].

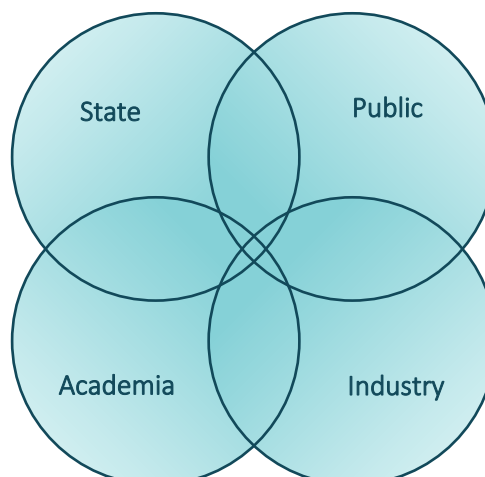


Fig. 3. The Quadruple-Helix framework (adapted from (Lindberg, Lindgren, and Packendorff 2014 [30]).

3.2.3 *The Quintuple-helix Framework*

The quintuple-helix framework was introduced a year later by the same authors of the Quadruple-helix framework [7]. The innovation model is broadened further by adding a fifth helix: the natural environments of society as illustrated in Figure 4. In this model, the environment is regarded as a driver for knowledge production and innovation and encompasses all other helices. If knowledge creation and education on sustainable development are stimulated and invested in, it will increase human capital, in turn creating opportunities in the economic sector, such as new jobs, products, and services, as well as new values concerning sustainability. These new values will be taken over by the media-based and culture-based public, creating more incentives for additional knowledge creation and sustainable development, until it becomes part of the political agenda. Knowledge is then circulated back into the education system, the economic system, the environment, and the public [20].

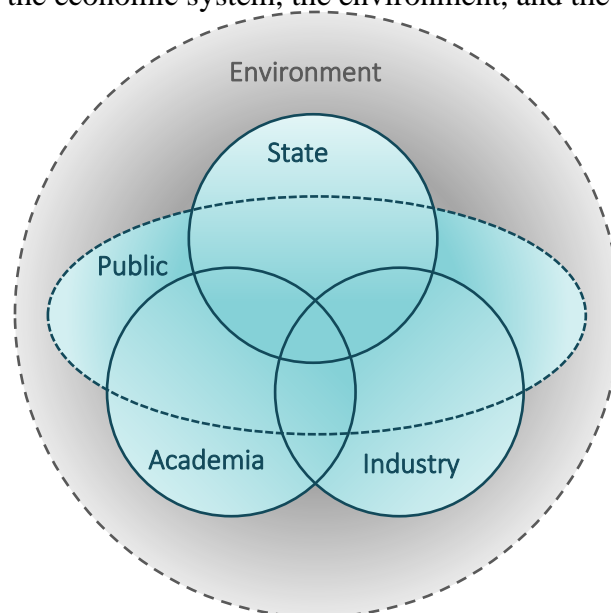


Fig. 4. The Quintuple-helix framework (adapted from (E. G. Carayannis, Barth, and Campbell 2012 [20]).

3.2.4 *The Penta-helix Framework*

In 2020, Igor Calzada proposes to extend the triple- and quadruple-helix frameworks from a social innovation perspective by including a helix for ‘social entrepreneurs/activists’, as shown in Figure 5 [31]. The penta-helix model was constructed to respond to the need for a multi-stakeholder approach in smart city policies and the resulting social/business models. The author argues that the triple- and quadruple-helix frameworks are too focused on institutions while neglecting entrepreneurial cooperative networks of individuals and civic groups. This way, smart city policy is becoming more technocratic than democratic and citizen-focused, especially with the increased use of algorithms. The penta-helix framework emphasises the role that people and organisations play in connecting the other four helices of the framework, therefore enabling more diversity in multi-stakeholder composition, and resulting business/social models, the use of intermediaries between institutions, and the experimentation with democratic arrangements instead of a technocratic Public-Private-Partnership model. The application of the penta-helix multi-stakeholder social innovation framework was investigated through fieldwork action research, comprised of desk research, interviews, and workshops of three smart city case-studies showing promising results [31].

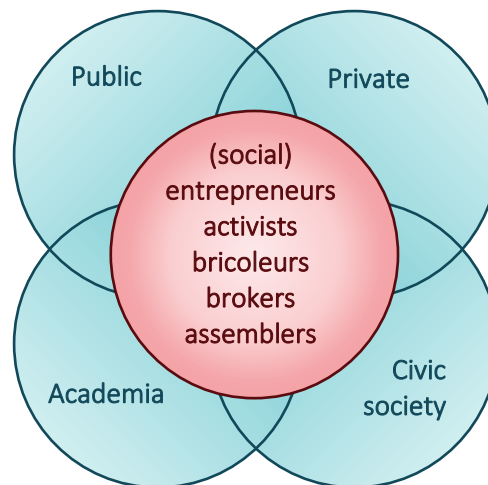


Fig. 5. The Penta-helix framework (adapted from Calzada 2020 [31]).

3.2.5 *The Neo Triple-helix Framework*

The Neo triple-helix framework was introduced by Cai and Lattu in 2022 [32] and it integrates the triple-, quadruple-, and quintuple-helix frameworks, inspired by the work of evolutionary biologist Richard Lewontin ‘The Triple Helix: Gene, Organism, and Environment’ [33]. Lewontin argues that genes, organisms, and environments should not be seen as separate entities, but as part of an organic process, and that genes are not blueprints that determine the development of an organism, but that the interplay between the three components is much more complex than generally assumed. Cai and Lattu make a comparison between the processes described by Lewontin and the dynamics of innovation ecosystems. This analogy is purely metaphorical and serves to simplify the complexity of the issue. The authors argue that the triple-helix institutions (i.e., state, academia, and industry) represent the genes in Lewontin’s model, social structures (as described in the quadruple-helix framework) represent organisms, and the environment is the natural environment in which we all operate (as was added in the quintuple-helix framework) (Figure 6). This model emphasises both the interactions between agents and those between agency structures and is aimed to enable concepts like sustainable innovation, cross-sectoral interactions, transnational spanning, and indirect relations. It is different from the quintuple-helix framework in that it envisions the triple-helix institutions on a different theoretical plane of existence than social structures and the natural environment. The Neo triple-helix model thus rethinks the theoretical grounds of the other helices and tries to clarify their interrelations, while highlighting the transnational nature of innovation ecosystems [32].

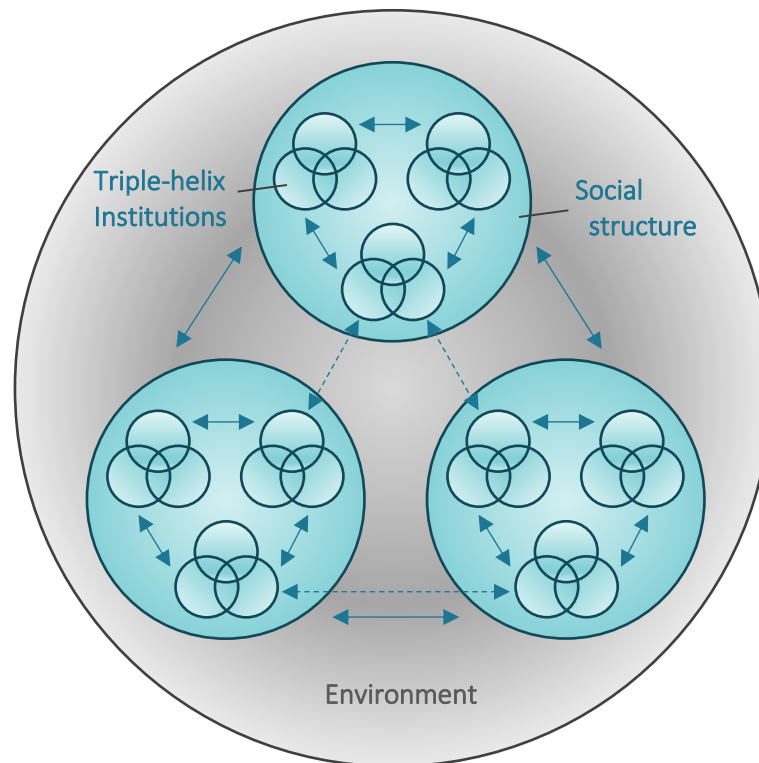


Fig. 6. The Neo triple-helix framework (adapted from Cai and Lattu 2022 [32]).

3.3 Expert Consultation on Smart and Inclusive Age-friendly Environments

The consultation session with experts in the field of age-friendly environments led to invaluable insights regarding the needs and gaps of current offers on age-friendly environments. Most gaps identified were related to socio-economic aspects, including affordability, accessibility, and adaptability. The experts noted that market value often has a higher priority than user centricism during the initiatives' development and that many stakeholders are not engaged or do not collaborate with each other. Furthermore, there is a need for clear standards regarding interoperability and privacy, as well as more support from policymakers, leading to more personalised solutions that are inclusive and accessible for the end-users. Based on the consultation, we propose that initiatives on responsive and inclusive age-friendly environments must be:

- **User-centred & expert-driven:** with a bottom-up and top-down approach through co-creation workshops with primary end-users, experts, key informants, policymakers, and other stakeholders (caregivers, organisations, and businesses).

- **Value-driven & multi-level:** value-driven instead of market-driven, by including a multi-stakeholder approach and a *glocal* perspective. Both quantitative and qualitative data are necessary to avoid *datafication* and to ensure a more inclusive and multi-level smart environment.

- **Accessible to a wide range of people:** technologies and services should be affordable, interoperable, available (open source), understandable (user-friendly), and inclusive. International collaboration between stakeholders is essential.

- **Implementable & Sustainable:** ICT should be capable of handling increased networking demands, regulations should be updated, and implementation should not be hindered by procurement processes. Innovations should be eco-friendly and cost-effective, and

financing schemes, quality management, and population density should be considered during development.

• **Replicable & Scalable;** integrated smart solutions should be made in such a way that they can be reproduced and adapted to different environments and operating systems and adhere to different policy schemes and territory-specific standards and needs.

3.4 *The Transnational Local-sphere Model – a New Framework for Smart and Inclusive Environments*

Based on the results of the literature review and the gaps and needs identified in the expert consultation, we propose the **Transnational Local-sphere model** as a combination of the Neo triple- and the Penta-helix models, incorporating interrelations between ecosystems, eco-friendly design, and sustainability, as well as citizen-focussed replicable development and diversity in choice. This model builds on knowledge production mode 3, which calls for the existence of multiple separate innovation frameworks that are in a balance of cooperation and competition (*co-opetition*) on both a global and local (*glocal*) level. This would increase interdisciplinarity and diversity, be more democratic than technocratic, and allow for the construction of a much wider variety of innovation initiatives. However, current policies do not fully accommodate mode 3 innovation production as of yet. Most knowledge-based economies still use economic-based models, which are inadequate for the growing need for more sustainable development [29]. Policy needs to support public, non-profit, and private actors, shifting the focus to the social aspects of social innovation.

Even though structural changes in policies would be most beneficial for the creation of a large-scale social innovation ecosystem, a clear framework for implementation can improve collaboration between local ecosystems and foster transnational initiatives. Projects completed between 2015 and 2022 most often used the quadruple helix model for their innovation scheme, but with the increasing pressure of the public towards ‘eco-friendliness’ more recent initiatives also incorporate the environment, as described in the quintuple-helix framework. It must be noted that in literature the concepts ‘quintuple-helix’ and ‘penta-helix’ are often used interchangeably. The quintuple-helix framework, as described by Carayannis and Campbell [7], is more widely accepted and more referenced showing the growing importance of a socioecological transition of our society and economy, in which eco-friendly design should form an integral part of any innovation idea.

Nonetheless, the penta-helix framework, proposed by Calzada [31], covers important issues as well, when it comes to smart city development, taking a multi-stakeholder approach and focusing on user-centrism, implementation, and replicability. Including a wider range of stakeholders and sectors, such as social innovators, entrepreneurs, and activists, has proven beneficial in making smart city solutions more sustainable, which is a vital part of building age-friendly responsive environments.

At the same time, the Neo triple-helix framework proposed by Cai and Lattu [32], even though it is still a conceptual model, also raises valid points. This framework incorporates all the elements of the Quintuple-helix framework but rethinks the theoretical grounds of all the helices and intends to clarify their interrelations while highlighting the transnational nature of innovation ecosystems. Because current SI ecosystems are scattered in nature using territory-specific policies, a focus on transnational collaboration could help in bridging local biomes and creating global standards. In addition, there seems to be a fundamental challenge with envisioning the institutions of the triple helix on the same level as concepts such as public opinion, the media, civic society (the fourth helix) and the environment (the fifth helix).

To summarize, the Transnational Local-sphere model proposed in this work and illustrated in Figure 7, builds on previous existing innovation frameworks, remaining true to the environmental and ecosystem aspects (from the Quintuple-helix framework), and at the same time incorporates newer ideas on democratic policy-making and transnational spanning (from the Neo triple- and Penta-helix frameworks). The Transnational Local-sphere model emphasizes the connection between existing local SI ecosystems while creating a trans-sector network of stakeholders to ensure an accessible and sustainable result for its users.

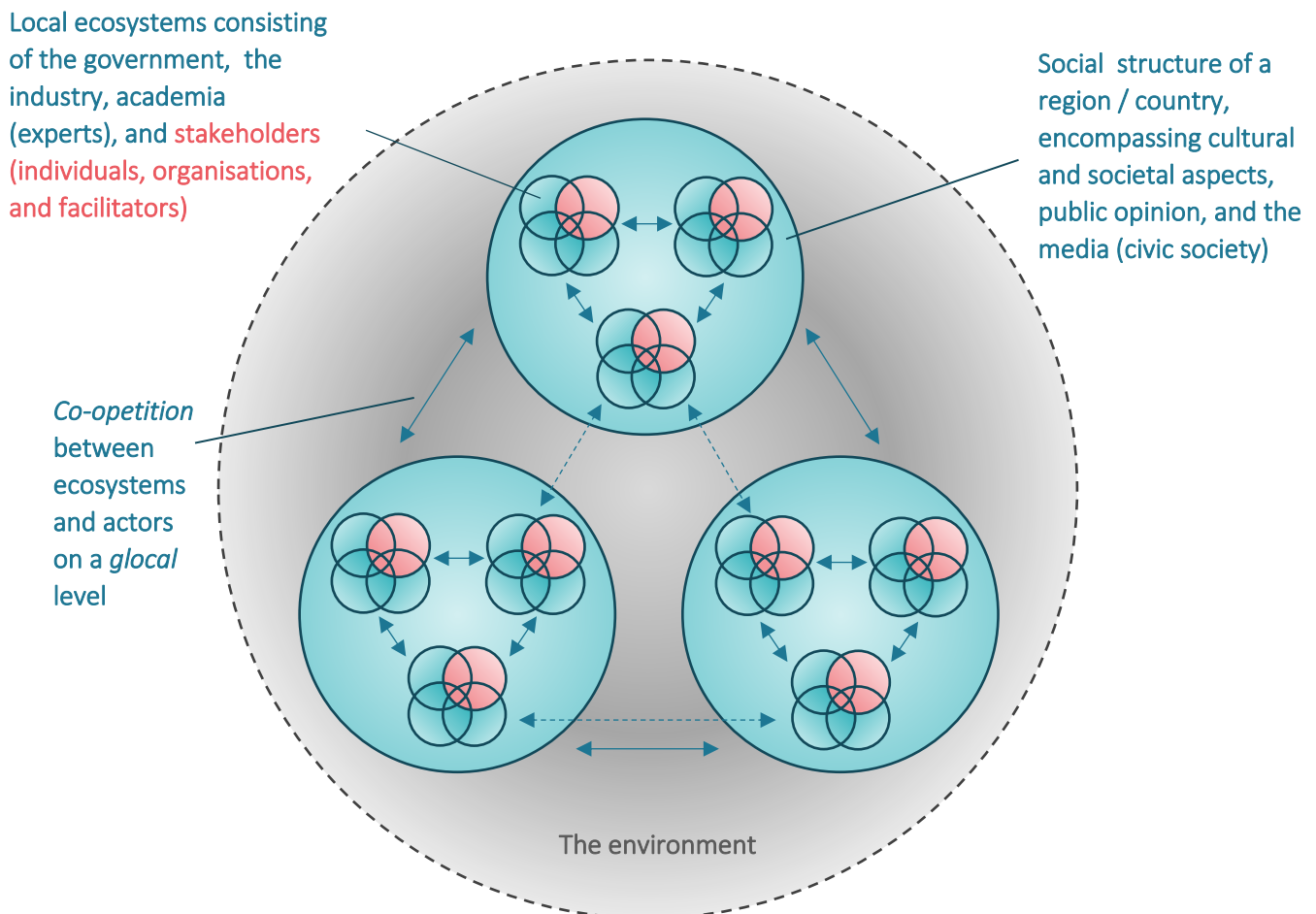


Fig. 7. The Transnational Local-sphere Model.

Discussion

This work explores the challenges of adopting innovation models in the creation of smart and inclusive age-friendly environments in a constantly changing context, recognizing the increasing importance of a multi-stakeholder approach in transnational settings, which can now play an active role in the innovative process of co-creation solutions. This paper contributes to the literature, providing holistic visions of global ecosystems. Practical implications are also emphasised, where collaboration and competition between different stakeholders are seen as drivers of sustainable value and cost-efficiency.

Knowledge production modes describe the way knowledge is produced and resulted from the transformation in how science was organised towards the end of the 21st century [34]. Knowledge production is a vital part of innovation and is therefore an inherent part of innovation frameworks. In innovation studies, the triple and quadruple helix models are among

the most popular conceptual frameworks, both of which have been broadly applied in empirical investigations. Other helix models later derived from these theories in response to continuous changes in our knowledge society, i.e., a growing public awareness of the socio-ecological transition [7], the need for a multi-stakeholder approach in smart city policies [31], and calls for building synergies between previous helix models [32]. Although these later adaptations have known less to no empirical studies, the concepts are part of the advancement of helical approaches and contain relevant insights into new opinions and ideas in innovation processes. From the analysis of these existing helix frameworks and input from a consultation with experts on the field of age-friendly environments, a new model was proposed combining elements from the researched models, to better align with the needs and gaps of responsive environment solutions and large-scale sustainability.

The Transnational Local-sphere Model proposed in this article builds on previously proposed helix frameworks, combining the crucial element of interrelations between ecosystems (Neo Triple-helix model) with the high relevance of underrepresented entities (Penta-helix model). Our model supports the identification and roles of the stakeholders, provides insights into the elements of the environments that should be considered, and demonstrates the relations between actors and institutions of various regions. The outermost circle represents the environment since eco-friendliness must be at the heart of all processes. The smallest circles represent local ecosystems within the cultural and societal structure of a certain region or country (the bigger circles). For the development of smart environments, a multi-stakeholder approach must be facilitated. This includes the three triple-helix actors, i.e., local and regional government authorities, researchers, and the industry, but also individuals, such as people in need of care, relatives and informal carers, and organisations, like health or service providers, the (social) housing sector, construction and installation businesses, real estate agents, energy suppliers and ICT companies. By including a wide range of stakeholders in a transnational setting, smart environment solutions will be both user-centred and expert-driven, as well as better implementable, more sustainable, and accessible to a wider range of people. International collaboration between stakeholders is essential, as well as replicability and scalability, so that solutions can be provided globally, but adapted to different local settings and adhere to different policy schemes and territory-specific standards and needs. The collaboration and competition (*co-opetition*) between the different stakeholders ensure a value-driven, cost-effective, and inclusive solution.

4.1 Practical applications in the context of Smart Healthy Age-Friendly Environments

The Transnational Local-Sphere Model was proposed with a core application field within the context of social innovation for the development of smart and inclusive environments. In line with the Sustainable Development Goals defined by the United Nations [35] – particularly 3. *Good Health and Well-being*, 9. *Industry, Innovation and Infrastructure* and 11. *Sustainable Cities and Communities* – the Smart Healthy Age-Friendly Environments (SHAFE) Thematic Network, was approved by the European Commission, to draw the attention of policymakers, organisations and citizens to the need for better alignment between health, social care, built environments and ICT, both in policy and funding [36]. SHAFE answers to the needs of an ever-changing society, in which every citizen has appropriate solutions to their needs, despite of their age, gender, and health situation. Modern living spaces are expected to be accessible, affordable, smart, energy-efficient, safe, secure, and comfortable. For many, our homes and living environments have been transformed over the years: they have become

greener, more efficient, safer, and more automatised. However, the next step is to design or reconfigure them to be more versatile, easy to enter, and easy to navigate in and around, to better meet the changing needs of occupants over their lifetimes. And, of course, ensure they are environmentally friendly, including concerning the materials used, the energy or water consumption, and the use of local suppliers, among others.

The Transnational Local-sphere Model aims to support the creation of SHAFE by providing a framework to enable social innovation and entrepreneurial knowledge, by creating alliances and synergies between different stakeholders within ecosystems and between ecosystems. This will promote the right conditions for large-scale investment in building, retrofitting and adaptation of the housing market aligned with the available ICT solutions and a green approach to the market segment, enabling the potential of the Digital Single Market and the Green Deal, towards more inclusive and resilient societies. The possibility of offering a quality benchmark that is relevant to those investing in social innovation for the physical design of products, homes and the Information Technology infrastructure within it, is essential to respond to the changing needs of an ageing population and the associated imperatives that call for people to play a greater part in maintaining their wellbeing and managing their health.

4.2 *Potential impact in other fields*

Even though social innovation ecosystems have not been broadly implemented on a large scale, various countries and regions are taking steps towards it by using a bottom-up approach and developing innovative ICT solutions. However, due to this scattered growth of social innovation ecosystems, policies are often territory-specific, and standards are lacking. For the existence of a large-scale social innovation ecosystem, change is needed to better integrate the profit-oriented way of the entrepreneurial system with non-profit public and private actors, increasing its focus on the potential value of SI solutions. This will require a change in governance models, supportive infrastructures, and legal and cultural norms; a gargantuan task that will take many years to accomplish. Therefore, for the short and mid-term transformation, it is important to foster interrelations between local ecosystems and to focus on building a transnational collaboration network to better support the creation and implementation of social innovation solutions and improve the replicability and scalability of current offers. The Transnational Local-sphere Model is a theoretical framework that enables this collaboration between local ecosystems. It could form the basis of various social innovation initiatives as a way of connecting existing networks and bridging territory-specific regulations and standards by focussing on a trans-sector multi-stakeholder approach in a transnational setting, *glocal co-opetition* between organisations and regions, and the incorporation of cultural and societal aspects when replicating and scaling solutions.

Conclusions

To accommodate the needs of an ever-changing society, smart and inclusive age-friendly environments must be user-centred and expert-drive, value-driven and multi-level, accessible and inclusive, implementable and sustainable, and replicable and scalable. In order to reach these criteria, transnational collaboration between a wide range of stakeholders is necessary but at times difficult to establish due to territory-specific policy schemes and the exclusion of stakeholders from various sectors and backgrounds. A transnational multi-stakeholder approach is needed to ensure the implementation and sustainability of smart housing solutions. When looking at the evolution of knowledge production modes, this approach corresponds with mode 3, which calls for the integration of socio-economic, political,

technological, and cultural aspects into a larger innovation ecosystem. However, expert consultation has shown that the current entrepreneurial ecosystem is too profit-oriented and current policy schemes are unsuitable for such an ecosystem to exist at this time. In this work we introduced a theoretical helix model – the Transnational Local-sphere Model – that focuses on connecting smaller, already existing ecosystems in a transnational setting, to bridge local biomes and territory-specific standards for the creation of a sustainable, replicable, and scalable approach in the development of responsive, inclusive, eco-friendly environments. The Transnational Local-sphere Model incorporates interrelations between ecosystems, eco-friendly design, and sustainability, as well as citizen-focussed replicable development and diversity in choice. This model focuses on stakeholders, organisations, and underrepresented entities, is user-centred by using a bottom-up approach, includes (trans)national collaboration and competition (co-opetition), is *glocal* by integrating global and local ecosystems, and involves civic society, through the media and the public.

Although the model was conceptualized within the context of smart healthy age-friendly environments, it is promising for other contexts that require social innovation approaches. Future work will focus on the empirical evaluation of the Transnational Local-sphere Model to form alliances and synergies between stakeholders within and between ecosystems, enabling social entrepreneurs to find potential business opportunities, funding and investment, and helping business actors in accessing social innovation opportunities and relevant entrepreneurial knowledge.

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Additional material

Leading questions for the gap analysis of responsive, inclusive eco-friendly environments:

The results of our desk review show that most initiatives for age-friendly housing are technological solutions covering physical aspects, such as safety, comfort, accessibility to systems in the house, options to contact health services, and smart appliances. Personal, social, and economic needs however are underrepresented. This includes issues like the ability to have social contacts, proximity to facilities, affordability, autonomy and control, emotional connection to the location, removing stigmatisation, and choice.

1. Which of these underrepresented needs (personal, social, and economic) is the most pressing at this moment? [Poll]

2. Which (technological) solutions are still missing that could complement current smart housing offers to improve these personal, social, and/or economic aspects for the users? [brainwriting]

Most research and initiatives in the area of responsive environments focus on the needs of the end-users. However, there are many other stakeholders involved, each with their own wants and needs. This includes relatives and informal carers, and organisations, like health or service providers, local or regional government authorities, the (social) housing sector, construction and installation businesses, real-estate agents, and ICT companies.

3. Do you think that the needs of these stakeholders are represented enough in the development of responsive environments? [Poll]

4. Where are the main gaps / difficulties for the developers of responsive environments? [brainwriting]

5. How can we convince underrepresented stakeholder groups, like the building sector or real-estate agents, to invest in smart housing? [brainwriting]

6. Are there other important stakeholders that are currently not included in the development or implementation of responsive environments? [brainwriting]

7. In what areas is knowledge and/or research still lacking? [brainwriting]