Operationalising the quintuple helix in S3: Towards sustainable innovation in tourism

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Abstract

This paper analyses how the Quintuple Helix (QUH) may be designed as a tool for a more efficient operation of the Smart Specialisation Strategy (S3) and its current evolution towards the Smart Specialisation Strategies for sustainable and inclusive growth (S4+), considering tourism as a priority domain and how both can enhance each other. By combining the natural environment and societal actors into policy design, the study argues that adding the QUH model into S3 improves innovation governance. The proposed QUH–S4+ framework links five helices: academia, industry, government, civil society, and the natural environment, forming a collaborative system for sustainable and innovation-driven regional development. This approach assigns a pivotal role to the natural environment as a catalyst for knowledge production and innovation. The QUH emphasises cohesive interaction and knowledge sharing across cultural, political, and economic systems, where cross-regional cooperation can particularly benefit less developed regions that embrace green technologies aligned with the European Green Deal. Innovative technology solutions can completely transform tourism, making the vision of smart tourism a reality. The natural environment is a crucial element of the knowledge-building process, and innovation is particularly crucial since it helps to thrive, better serve humankind, and commit to green technology more successfully. Methodologically, the paper conducts a conceptual, theory-building review, deriving operational propositions and a policy checklist that translates the QUH framework into S3/S4+ implementation in tourism.

Keywords: Quadruple Helix; Quintuple Helix; RIS3; Smart Specialization Strategy; Tourism.

1. Introduction

The study of public policy in the European Union (EU) has grown in recent years mainly due to the economic crisis that has emerged in recent years, combined with the need to sharpen strategic public initiatives to improve regional economic performance necessity. As a result, the Smart Specialisation Strategy (S3) concept has gained traction. It features an innovative, place-based policy framework for regional economic growth, which is a fundamental concept and component of the EU's 2020 innovation program and the new cohesion policy reform. (Foray D., 2014; McCann & Ortega-Argilés, 2015).

S3 in the context of Research and Innovation for Smart Specialisation Strategy (RIS3) is a strategic approach to economic development through research and innovation-focused support. This notion is based on the idea that by concentrating knowledge resources and linking them to a limited number of core economic activities, countries and regions will compete in the global economy and stay competitive (Foray, 2014; Foray et al., 2009, 2012a).

Regional research and innovation policies are used to put the concepts described in S3 into action. The RIS3 promotes entrepreneurship and the building of territorial partnerships between diverse public and private players, as well as the establishment of the necessary conditions for long-term economic development. Local policymakers, universities, and private enterprises are major players in boosting knowledge and innovation (Camagni & Capello, 2013). In this sense, the evolution of innovative models from the Triple Helix (TH) and Quadruple Helix (QH) to the Quintuple Helix (QUH) is especially appealing to European regions. Furthermore,

concerning innovative models, the QUH model reinforces the interaction between public institutions, private organizations, research institutes, local agencies, and the general public within a single environmental system (Carayannis et al., 2012).

The fundamental question that arises is to what degree can S3 be employed with and within a natural environment towards sustainability (QUH model) when considering a specific domain such as tourism as a strategy to boost regional development. This essay aims to establish a meaningful relationship between the concepts to provide valuable insights into this discussion.

Results indicate that S3 is beginning to play an increasingly important role in how regions create their policy frameworks, particularly in less developed areas (Bailey & De Propris, 2019). However, establishing S3 goals considering tourism as a thematic priority for regions is only the beginning, as RIS3 is a continuous process of policy learning, experimentation, and implementation. In addition, extra-regional cooperation towards the QUH practice can benefit all but especially less developed regions, mainly if they result in quicker acceptance of new technologies in this specific case, green technologies, information exchange, diversification, related variety, and better capacities for a green and inclusive economy in line with the UN 2030 Agenda for Sustainable Development and Green Deal (McCann & Soete, 2020). Overall, RIS3 can improve regional resilience and its ability to capitalize on newly emerging market opportunities (Barzotto et al., 2019).

Recent EU guidance reframes S3 as S4+ (Smart Specialisation Strategies for Sustainable and Inclusive Growth) a mission-oriented, place-based logic that couples innovation with sustainability and inclusion through multi-level governance and stronger directionality. For tourism, this transition is anchored in the Transition Pathway for Tourism and the emerging European Tourism Data Space, which together provide the mission logic and the knowledge infrastructure to operationalise QUH in practice.

A quick rundown of the S3 in the sections below is presented. The models of knowledge creation and their major components are then introduced, followed by an in-depth discussion on the QUH on S3. Afterwards, we consider the key ideas and components and the connection between tourism, S3, and the QUH. Finally, the paper ends with some final remarks.

1.1. Methods (Conceptual Review)

We adopt a conceptual, theory-building review to synthesise QUH and S3; S4+ literatures with tourism policy and green/digital transition documents. We searched Scopus and Google Scholar (2014-2025) using combinations of “smart specialization/RIS3/RIS4/S4+”, “quintuple helix/quadruple helix”, “tourism transition pathway/data space/living labs”, and “related variety/creative and cultural industries”. Inclusion emphasised peer-reviewed articles, EU policy reports, and JRC guidance. We used an abductive approach: (i) map constructs; (ii) identify operational mechanisms per helix; (iii) derive propositions and a policy checklist. Limitations: we prioritise breadth over exhaustiveness and focus on EU-centric sources.

2. Smart Specialization Strategy

The EU's current economic development strategy is based on territorial-based policies aimed at promoting competitiveness by increasing socio-economic innovation capacity. The structuring axis of this strategy is S3, in which the current programs of Horizon Europe are based, and which had an influence already in the previous framework program.

The S3 that regions are challenged to achieve assumes that innovation and the competitiveness of regions should be based on their characteristics and assets existing in their territory, concentrating resources on the areas and economic activities in which there is or can be pooled with relevant critical mass, with the aim of creating value and employment. This approach to S3 reinforces the need for regions to reassess their competitive positioning according to the global market and their capacity for international affirmation (Asheim et al., 2017; Foray et al., 2012a; McCann & Ortega-Argilés, 2015).

S3, in the context of RIS3, is a strategic approach to economic development through research and innovation-focused support. RIS3 is a proposed "ex-ante conditionality" for a local approach to regional growth. Meaning that before they can obtain financial support from the EU through the Structural Funds for their planned innovation measures, all Member States and Regions must have a well-developed strategy (EC, 2014; Foray et al., 2012a). The concept is based on the idea that by concentrating knowledge resources and linking them to a small number of core economic activities, countries and regions will be able to compete in the global economy and stay competitive. (EC, 2014; Foray et al., 2012a). Hence regions cannot be competitive in all areas of knowledge, innovation, and technology. Therefore, it is necessary to prioritize to concentrate resources in certain areas, considering the existing capacities of the region. The purpose is to reinvent regional trajectories and create new ones, fixed in existing assets in the region, with the aim of diversifying the regional economic structure and increasing its innovative delivery, concentrating resources and skills in a set of areas where the region shows greater aptitude and installed resources (Foray, 2014).

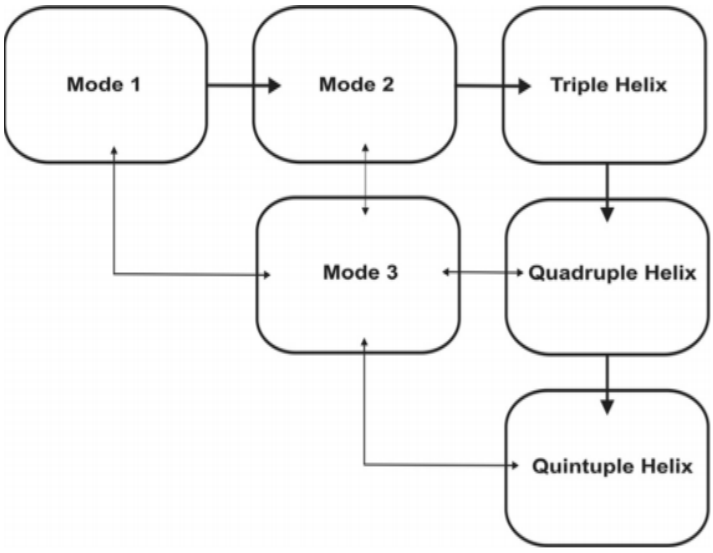
For the regional dynamics of innovation and the very system governance, the vision of a QH is commonly assumed as structuring of RIS3. However, the relevance of academia, government agencies, the business fabric, and users and other beneficiaries do play a key role in the implementation phase of this typology of strategy that must be endorsed with an entrepreneurial discovery process (EDP), where the foremost players try to find areas of knowledge and economic activities capable of becoming engines of economic change (EC, 2014; Foray, 2014; Foray et al., 2009, 2012a).

3. Models of Knowledge Creation

Knowledge has the potential to be a crucial factor in achieving long-term development success. Essentially, it should be known today that nation-states focused on societal growth, economic competitiveness, or a better and more sustainable quality of life must use information as a resource. In the transition to a knowledge-based society, knowledge-based economy, or knowledge-based democracy, there are several factors to consider (Carayannis & Campbell, 2009, p. 224), namely, the possibility to generate new and usable knowledge in conjunction with sustainable development under the guise of S3. As a result, knowledge becomes a highly vital resource (Lundvall, 1992).

Knowledge is developed as a resource through creative processes, combinations, and creations in so-called 'Knowledge models' or 'Innovation models,' and is thus made available to society: The authors also call this the 'creativity of knowledge creation' (Carayannis & Campbell, 2010a, p. 48). There are six current models of knowledge creation and innovation creativity as follows (Carayannis et al., 2012, p. 3):

Figure 1: Evolution of the models of knowledge creation.



Source: Carayannis et al. (2012, p. 3).

Associated with the Linear Innovation Model, Mode 1 (Gibbons et al., 1994), 'focuses on the traditional role of university research understanding' were a success. This production occurs mainly through fundamental research practised in universities or other higher education institutions, in a logic of separation of scientific fields, organized in a disciplinary structure. (Carayannis and Campbell 2011).

Mode 2 is typified by: (1) "knowledge produced in the context of application," (2) "transdisciplinary," (3) "heterogeneity and organizational variety," (4) "social accountability and reflexivity," and (5) "quality control" (Gibbons et al., 1994, p. 3). The transition that has occurred at the social system level, according to Mode-2, has transformed the way knowledge is produced. They propose that scientific knowledge has become redundant and should be replaced with technical-scientific knowledge developed through transdisciplinary projects. It focuses on problem-solving through the application of knowledge.

The Mode 3 knowledge production system advocates that innovation networks and knowledge clusters are significant components for understanding the dynamics of stocks and knowledge flows. Through networks of variable configurations and platforms, universities and other higher education institutions and companies connect by creating innovation networks and knowledge clusters, emphasizing the coexistence and co-evolution of diverse modes of knowledge and innovation. Mode 3 supports interdisciplinary thinking and transdisciplinary application of multidisciplinary knowledge and the coexistence and co-evolution of diverse knowledge and innovation paradigms (Carayannis & Campbell, 2010a).

The TH model is an analytical tool for the study of the complex dynamics underlying the evolution of knowledge-based economies and innovation systems (Etzkowitz & Leydesdorff, 2000). The constant need to innovate increasingly reinforces the importance of knowledge for economic or innovation systems, intensifying the strengthening of networks of relations between 3 main axes - university, industry, and government institutions (Carayannis & Campbell, 2010a).

The QH Model adds the university, industry and government institutions, civil society, and the public, shaped by culture and the media. It attaches importance to the culture of knowledge and knowledge of culture, to values and lifestyles, to the heterogeneity and diversity of the modes of knowledge production and innovation. It puts the sciences and the arts in the same way and involves the concept of democracy of knowledge. In the design of knowledge and innovation strategies and policies, in the authors' opinion, the contribution of the public and media dynamics to the successful pursuit of goals and objectives should be recognized (Carayannis & Campbell, 2009, 2010a).

The QUH purpose and interest are to include the natural environment as a new subsystem for knowledge and innovation models, establishing "nature" as a major and analogous component of and for knowledge creation and innovation. The natural environment is essential for the process of knowledge production, and the creation of innovation is especially important because it aids in the preservation, survival, and vitalization of humanity, as well as the potential development of new green technologies. 'Sustainable development' and 'social ecology' become ingredients for social (societal) innovation and knowledge production with the helix of natural environment. As a result, the exchange of knowledge in a state (nation-state) is dealt with in a QUH by and via the five helices to foster knowledge-production-based sustainable development.

The Quintuple Helix Model is interdisciplinary and transdisciplinary at the same time: the complexity of the five-helix structure implies that a full analytical understanding of all helices requires the continuous involvement of the whole disciplinary spectrum, ranging from the natural sciences (because of the natural environment) to the social sciences and humanities (because of society, democracy, and the economy) (Carayannis & Campbell, 2010a, p. 62).

Overall, the QUH Model emphasizes the role of the environment of societies and economies as a driver for further advances in knowledge production processes and in innovation systems. It builds on the TH and QH models by adding a fifth helix to represent the natural environment, in which the environment or natural

environments are represented by the fifth helix (Carayannis & Campbell, 2010a). The Mode-3 innovation ecosystem frames the QH and QUH models and balances the non-linear models in the context of innovation systems, mirroring the coexistence and co-evolution of different paradigms of knowledge and innovation. Within the scope of the QH and QUH Models, the concept of Open Innovation Diplomacy (OID) emerges as a new strategy, an approach of making policy in terms of governance, essentially consisting in shortening distances and promoting initiatives to connect agents, ideas, markets, and solutions. *OID qualifies as a new and novel strategy, policymaking, and governance approach in the context of the QH and QUH innovation helices* (Carayannis & Campbell, 2011, p. 328).

To move beyond descriptive helices, we specify operational mechanisms, per helix, that convert QUH into governance routines (EDP cadence, data sharing, demand-side instruments) aligned with S4+ missions in tourism.

4. Towards a Quintuple Helix in Smart Specialization Strategy?

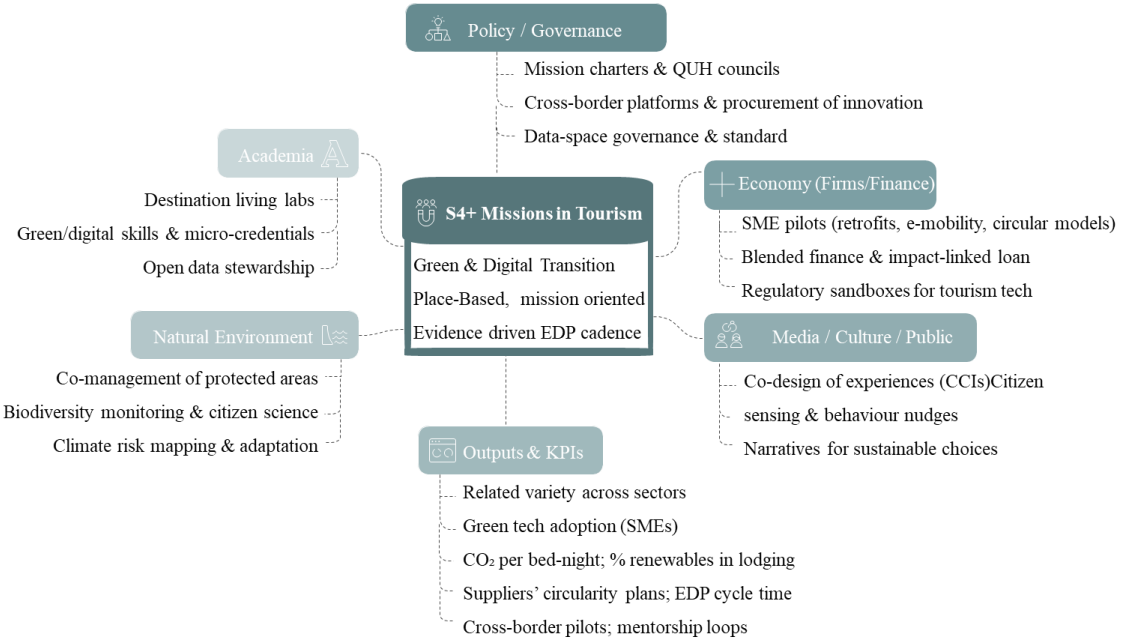
S3 enables regional and national policymakers to concentrate on several key processes in the knowledge economy and society, providing evidence that further facilitates innovation in a range of trans-disciplinary areas. The RIS3 focuses on the need to reinvigorate regional policies, hence stimulating the development of regional innovation systems, which must be conceptualized and executed with a top-down view, i.e., across government, university, and industry sectors and localities (Leydesdorff, 2012) complemented and enhanced by a bottom-up set of insights coming from the civil society. This is the operationalization of the QH innovation helix concept in the context of RIS3 (Carayannis & Rakhmatullin, 2014). (see Figure 2).

Figure 2: RIS3 Quadruple Helix.

Source: Authors' elaboration based on RIS3 Guide (Foray et al., 2012a).

Figure 2 recaps the canonical Quadruple Helix used in RIS3 governance. Building on this architecture, our contribution is to move from descriptive helices to operational mechanisms. Figure 3 therefore specifies, for each helix, concrete governance routines—EDP cadence, data sharing and demand-side instruments—and the outcome KPIs aligned with S4+ missions in tourism.

Figure 3: Operationalising the Quintuple Helix (QUH) for S4+ in Tourism - mechanisms by helix and outcome KPIs.



Source: Authors' elaboration based on Carayannis & Campbell (2010) and EC materials on S4+/Tourism.

Figure 3 summarises the operational mechanisms per helix that translate QUH into S4+ governance routines in tourism (EDP cadence, data sharing, and demand-side instruments). Building on this logic, KPIs for tourism S4+ missions can be operationalised with standardised indicator sets tested in outermost regions, covering energy, emissions, mobility and circularity at destination and firm levels. Recent work validates a portable grid of sustainable tourism indicators for RUP contexts, offering a ready baseline for CO_2 per bed-night, renewable energy uptake in lodging, and supplier circularity plans (Leite et al., 2022). This operational turn is coherent with recent theory linking creativity and entrepreneurship in policy design (the W.O.M.B. model) (de Almeida Leite, Audretsch & Leite, 2025).

While one identifies key operational mechanisms and outcome indicators for S4+ missions in tourism in Figure 3, a significant challenge lies in monitoring and measuring the long-term impact of these governance processes. The QUH-S4+ framework proposed in this paper embeds measurement as an integral part of its adaptive governance logic. The model views evaluation as a feedback mechanism that supports continuous learning and policy adjustment rather than as an external activity (Schot & Steinmueller, 2018).

Multidimensional assessment in three interconnected domains is necessary for long-term monitoring: (i) the intensity and diversity of multi-helix collaboration; (ii) the integration of sustainability and digital objectives within innovation projects; (iii) the evolution of tourism sustainability performance over time.

These dimensions can be operationalised using established European instruments such as the European Tourism Indicator System for Sustainable Destinations (EC, 2013), the ISO 37101 standard for sustainable development in communities (ISO, 2016), and the Regional Innovation Scoreboard in accordance with RIS3 monitoring practices (EC, 2025). This strategy aligns with the innovation policy principles of transformative learning and adaptive governance (Schot & Steinmueller, 2018). It is consistent with earlier studies on using indicator-based systems to measure sustainability in tourism (Torres-Delgado & Palomeque, 2014).

This approach depends on ensuring data interoperability between tourism observatories, statistical agencies, and regional innovation systems. To establish periodic monitoring cycles, for example, every three years, would track cumulative impacts and capture learning effects at all governance scales. In this way, the QUH-S4+

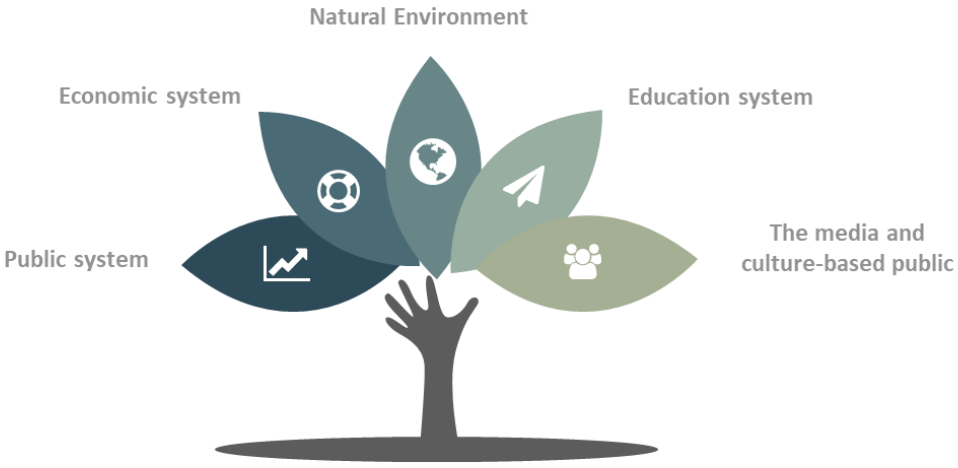
framework functions as a learning system, translating data into adaptive governance and supporting evidence-based transitions to sustainable and smart tourism ecosystems.

Although previous studies have proposed indicator sets for the Quintuple Helix model (e.g. Barcellos-Paula et al., 2021; Sudiana et al., 2020), there remains no standardised matrix covering all five helices within a tourism-specific S4+ context. Further empirical research will therefore be needed to validate and refine the indicator grid proposed conceptually in this framework.

The European Commission (EC) has set the goal of moving from a knowledge economy to a knowledge society, explicitly referencing the QH model of innovation (Carayannis & Campbell, 2009). More specifically, the QH model is based on the openness of innovation processes to civil society for the application of the S3, surpassing the third helix model developed by Etzkowitz and Leydesdorff (1997), which was based on the relationships between the public system, universities, and business. Pursuing the QH model, the users' orientation is expected to develop and produce, as well as to access new products, processes, and industrial services. At the same time, we need an additional step to identify a new layer of regional innovation processes. Moreover, the QUH stresses the importance of the natural environment as an asset to produce knowledge and innovation. The QUH model comprises five helices: the education system, the economic system, the natural environment, the media- and culture-based public, and the political system (Carayannis & Campbell, 2010a).

For completeness, Figure 4 restates the generic QUH architecture that underpins these mechanisms, highlighting the natural environment as the fifth helix.

Figure 4: Quintuple Helix.



Source: Authors' elaboration based on Carayannis and Campbell (2010).

The natural environment is considered a central element to produce knowledge and innovation, being a unique source for the very survival of humankind. The creation of new green technology and innovative processes geared towards sustainable development become fundamental for fostering innovative long-term strategies. Protection of the Environment and biodiversity propels knowledge and innovation in the direction of a sustainable and social economy where all the actors are involved and responsible for the formulation of strategies for local development. The model is a framework for transdisciplinary analysis of sustainable development and social ecology that is capable of rendering less developed regions more competitive (Carayannis & Campbell, 2010a).

Within S3, the innovation is increasingly seen as an open system where multiple actors collaborate to foster inclusive governance that encourages both conventional and new innovators (Provenzano et al., 2018). New political aspirations are needed so that innovative practices and green technology solutions drive sustainable development; the environmentally conscious use of resources becomes a key factor for long-term strategies that will lead to interconnections or cross-border linkage between dominant and bordering regions (Carayannis et al.,

2012; Provenzano et al., 2018). As a side effect, the evolution of innovative models such as the QUH, which aims to strengthen the interaction between public institutions, private organizations, research institutes, local agencies, and the public within a single environmental system, is particularly appealing to lagging regions (Provenzano et al., 2018).

5. In the Field of Tourism, How Would a Smart Specialization Strategy Incorporate the Quintuple Helix Model?

It is critical to ensure that all S3 adopted by EU regions and Member States are anchored on a solid foundation in terms of priorities, governance, cooperation, monitoring, and evaluation over the current programming period 2021-2027. Deepening S3 also entails including the sustainability dimension, which is critical for meeting the EC's objective for achieving competitive sustainability. In addition to its economic and social foundations, SS's green dimension must be reinforced, in line with the European Green Deal.

Concretely, the Transition Pathway for Tourism specifies priority actions for green and digital upgrades, while the Tourism Data Space underpins interoperable, privacy-preserving data sharing across destinations and firms. Together, they shorten EDP cycles, inform evidence-based prioritisation, and enable cross-regional learning consistent with QUH.

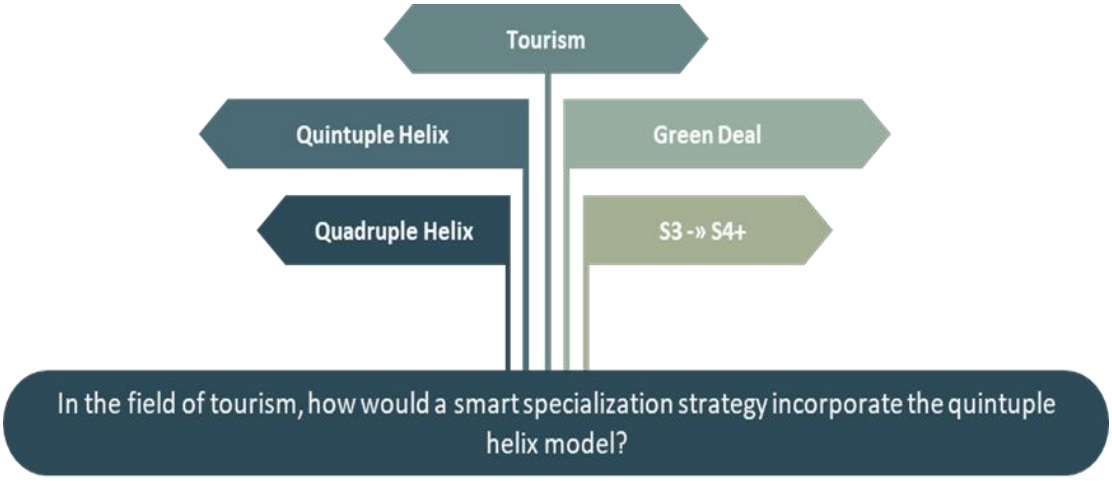
The EC prioritized sustainability and European values in its long-term policy agenda, the European Green Deal lays out a roadmap for the EU to achieve carbon neutrality by 2050. The UN Sustainable Development Goals (SDGs) will guide policy efforts and changes in Europe and beyond. This is a policy agenda based on innovation for new systemic solutions and job development as a result of the ecological and digital transformations (McCann & Soete, 2020).

As McCann and Soete (2020) eloquently phrase it: *the European Green Deal is at the same time the EU's Moonshot mission and its global S3*. They do emphasize, however, that this journey will not be without its challenges. A sustainable place-based innovation policy will necessitate multi-level solid governance and policy flexibility to address potential adjustments soon. On the other hand, bottom-up leadership must be combined with a new directionality of sustainability and inclusion. The authors refer to this as the transition from S3 to S4+ (smart specialization strategies for sustainable and inclusive growth).

McCann and Soete (2020) propose a shift in policy logic from S3 to (S4+), using a non-neutrality, direction, and system approach to involve regions in European initiatives to reinforce the S3 mission-oriented policy approach. S4+ denotes a policy shift in how regions think about defining policy priorities to encourage technological innovation and regional solutions to societal concerns.

According to the information presented in this essay, the QUH is an adequate model in principles and application for society to perceive the link between knowledge and innovation, to promote ongoing development. This contribution, under the theme of S3, focuses on the following crucial question: how can sustainable development regarding S3 be practised with and within a QUH model, considering a specific domain such as tourism?

Figure 5: S3, QUH and tourism.



Source: Authors' creation.

Because tourism is a critical industry for several places and boosting it suits well within a cross-sectoral logic, S3 is a viable policy framework for tourism (Benner, 2017; Del Vecchio & Passiante, 2017; Weidenfeld, 2018). A new policy mix centred on interconnecting determined priority thematic areas with other cross-cutting concerns like tourism and ICT to displace fragmented government policies (Bečić & Švarc, 2015).

A concrete illustration of related variety within tourism ecosystems is the rise of digital nomads in island regions. Evidence from Madeira documents how new workleisure mobilities trigger cross-sector linkages (accommodation, co-working, CCIs, mobility services), consistent with QUH dynamics and with our Proposition P2 (Sardinha et al., 2023).

To incorporate the sustainability dimension, tourism appears as an asset in pursuing SS. Due to the diversified range of services that make up a destination's production chain, tourism has much potential to become a central feature of S3. (EC, 2016; Weidenfeld, 2018). Also, a wide variety of economic activities is required to supply products and services in a tourism destination, establishing a decentralized value chain that facilitates the formation of different ties and exchanges within local and regional economic systems. (Erkuş-Öztürk, 2016; Romão, 2020a, 2020b). As a result, tourism emerges as a viable economic activity capable of forging intra-sectoral solid interconnections promoting innovation and long-term sustainability (Benner, 2020; Lazzeretti et al., 2016). Furthermore, knowledge externalities and spillover effects emerging from the development of a creative regional economy, where various industries contribute to diversifying regional economic structures, might promote tourism development and innovation (Aarstad et al., 2016; Bečić & Švarc, 2015; EC, 2016; Romão, 2020b; Romão & Nijkamp, 2018).

According to Benner (2020), SS presents an opportunity for economies to revitalize their tourism development strategies by connecting tourism to other sectors and priorities in order to promote tourism environmental sustainability, keeping in mind that the green deal is seen as a path to the green transformation of the tourism ecosystem.

Benchmarks help regions position their strategies. Eye@RIS3 reveals how many regions prioritise tourism and adjacent domains (e.g., CCIs, health, blue economy), supporting related variety plays. Cross-regional alliances (e.g., RIS4-oriented networks) operationalise extra-regional cooperation, a key QUH lever for lagging regions.

In outermost regions, intermediation capacity has been mobilised via the OSEAN initiative, which orchestrates QUH actors around mission-oriented pilots (skills, digitalisation, sustainability) and cross-border exchanges, an example aligned with P1 and P4 regarding living labs and policy brokering (Leite & Leite, 2024). Complementarily, network studies of resilient innovation ecosystems in EU Outermost Regions highlight the role of critical assets

and value networks for implementation effectiveness—again consistent with our moderation claim in P4 (Schwabe et al., 2025).

According to Turismo de Portugal[1], within the framework of the green deal strategy, there are several initiatives proposed by the Commission that may have, in the short/medium term, a direct or indirect impact on tourism:

- "Proposal for the Climate Law, which establishes the objective of carbon neutrality in the EU by 2050
- Review of existing environmental legislation: CELE (Trading in CO2 Emissions), Use of Land and Forests; Energy Efficiency Directive; Energy Taxation Directive (Electricity VAT)
- New EU Climate Change Mitigation Strategy, especially for coastal regions (relevance for coastal tourism activities, especially given the potential reduction in the attractiveness of these regions)
- New smart planning strategy, including land planning
- Public building recovery initiative (hotel schools, airports, tourism support infrastructures) and private (tourist developments and related infrastructure)
- New Action Plan for the Circular Economy
- EU strategy "from meadow to plate" to be complemented with national strategies in this field
- 2030 Biodiversity Strategy, where the Sustainable Tourism aspect may have a strategic contribution
- New EU Zero Pollution Strategy, which will include the proposed action plan "zero pollution for water, air and soils"
- Improvement in the statistical production and auditing processes of companies, avoiding "greenwashing" (unjustified appropriation of environmental virtues by organizations – companies, governments – or individuals, using marketing techniques)".

Delivering these ambitions requires digital maturity and future-skills across the ecosystem. Editorial guidance in JER frames “digital creativity” as a lever for capability-building in SMEs and public administrators—precisely the skills dimension embedded in S4+ and in our helix-specific mechanisms (Figure 3) (Vezzani et al., 2024).

Innovative technology solutions have the potential to completely transform this industry, making the vision of smart tourism a reality. Moreover, by investing in the environmental sustainability of the tourism sector, sustainable, smart, and green tourism are becoming valuable and tangible. Reductions in energy use and harmful pollution will result in a more economical, socially, and environmentally sustainable tourism industry.

Climate-transition pressures in hospitality are now systematically mapped: a recent systematic literature review identifies adaptation and mitigation fronts in lodging (energy retrofits, water, waste, mobility), reinforcing the priority of green-tech adoption and measurement in our S4+ KPI set (Mota, Leite & Ghasemi, 2024).

Nevertheless, governments have a critical role in setting the necessary conditions to pursue the digital transformation for the tourism ecosystem. Therefore, to maximize the value of digitalization is necessary an integrated and cohesive policy measure.

5.1 Propositions and testable implications

Building on the QUH–S4+ rationale and the tourism policy pathway discussed above, we advance four testable propositions to guide empirical work and policy evaluation in tourism ecosystems:
The QUH–S4+ framework integrates the ecological and social dimensions of innovation into regional policy design. It assumes that innovation for sustainability depends on collaborative governance, evidence-based decision-making, and systemic learning mechanisms. Based on research on the QUH model (Carayannis & Campbell, 2010b) and S3 (Foray et al., 2012b; McCann & Ortega-Argilés, 2016) the following propositions explain how this integration could improve the shift to S4+.

[1] https://business.turismodeportugal.pt/en/Conhecer/Oportunidades_UE/programas-iniciativas/Pages/european-green-deal-pacto-ecologico-europeu.aspx

P1. Regions with QUH operational living labs exhibit higher green-tech adoption in lodging and mobility than comparable regions without labs.

P2. A formal S4+ mission is positively associated with related variety between tourism and CCIs/health/blue economy.

P3. Participation in a Tourism Data Space accelerates EDP cycles and reduces information asymmetries, increasing SME innovation outcomes.

P4. Intermediation capacity (policy brokers/authorities) moderates the relationship between S4+ design and implementation effectiveness.

Note: These propositions are designed to be operationalised with standard indicators (e.g., CO_2/bed-night, % renewable energy in lodging, number of cross-sector linkages, EDP cycle time, SME innovation outputs), enabling comparative analysis across regions.

Together, these four propositions outline a conceptual architecture for embedding the Quintuple Helix within Smart Specialisation to advance S4+. Although they were conceived theoretically, they are already observable in practice in the growing policy and innovation ecosystems of European tourism, particularly those organised as Living Labs that test sustainable integration and multi-actor collaboration. The following section presents such illustrative cases, highlighting how the principles of the QUH–S4+ framework are being interpreted and tested within ongoing European initiatives.

6. Living Labs as Emerging QUH-S4+ Ecosystems

This section builds on the theoretical propositions mentioned above by giving examples of how the principles of the QUH-S4+ framework are being used and understood in current tourism innovation projects. These cases are not empirical tests of the model but examples of alignment between S3 and the multi-helix logic of collaborative, sustainability-oriented governance. Each case reflects one or more of the Propositions 1 to 4, showing how the framework's underlying mechanisms can manifest across distinct governance levels and territorial contexts.

The Spain Living Lab (SLL)[2] is a nationwide open innovation ecosystem designed to revolutionise the tourism sector by transforming its economic model into one based on Artificial Intelligence (AI). Led by the Canary Islands and funded by European RETECH funds, the project involves seven autonomous communities: the Canary Islands, Navarre, Andalusia, Aragon, Asturias, Castilla-La Mancha, and the Balearic Islands.

The main goal is to create a positive feedback loop of innovation by using Living Labs (businesses that test disruptive technologies) to generate data, sharing that data in Data Spaces, and using that data to develop AI. This organization seeks to increase the sector's competitiveness and promote an innovative culture. More than 300 hotels and 450 travel agencies in Spain will be converted into data labs, generating information for the predictive improvement of demand, pricing, products, and experiences. SLL utilises technologies such as AI, Virtual and Augmented Reality (VR/AR) to create hyper-personalised systems and achieve maximum efficiency.

The project explicitly describes itself as structured within a quintuple-helix framework, linking academia, government, business, civil society and environmental actors. This configuration reflects Proposition 2 (multi-helix knowledge co-creation) and Proposition 4 (multi-scalar coordination) of the QUH–S4+ model:

- Proposition 2 is visible in the co-development of shared data and sustainability solutions among research, business, and policy actors.
- Proposition 4 is observable in the project's vertical coordination, where national governance interacts with regional adaptation and experimentation.

[2] Spain Living Lab

The **Alimara Living Lab (ALL)**[3] is an open innovation ecosystem and a real-world experimentation environment based at the Alimara University Hotel in Barcelona. Driven by the CETT Barcelona School of Tourism, Hospitality, and Gastronomy, ALL aims to drive change and innovation in the hospitality and restaurant sectors. It serves as a platform for collaboration, bringing together businesses, organisations, researchers, and experts to develop and test ideas jointly. Process optimisation, risk mitigation, and enhancing customer satisfaction and operational effectiveness are the main goals of ALL's services.

The lab operates in three main areas: the hotel/gastronomy industry, the technology sector (tech), and the equipment/design sector (contract). ALL uses participatory methods (design thinking) and promotes sustainable transformation, encompassing areas such as Circular Economy and Emerging Technologies. Its activities covering circular hospitality, responsible urban tourism and digital transformation mirror Proposition 1 (sustainability-oriented collaboration) and Proposition 2 (multi-helix co-creation):

- Through sustainability-focused projects, the Lab integrates environmental and social dimensions into innovation, as envisaged in Proposition 1.
- Its collaborative platform, involving university, business and policy actors, embodies Proposition 2, reinforcing the knowledge-exchange logic of the Quintuple Helix.

The ALL thus operationalises the role of universities as policy intermediaries, mediating between scientific knowledge and policy implementation, an aspect central to the QUH-S4+ framework.

The Urban Leisure and Tourism Living Lab (ULTL)[4], rooted at Inholland University of Applied Sciences, operates in Amsterdam North and Rotterdam South, off the beaten tourist track. The Lab redefines tourism, using it as a lens to improve the quality of urban life, rather than viewing it as an end in itself. Its focus is on making tourism act as a catalyst for social cohesion, healthy urban development, and regenerative placemaking.

ULTL focuses on hyperlocal engagement, ensuring that tourism serves communities rather than burdening them. The QH (residents, businesses, municipalities, and students) and the QUH (including nature itself, such as programs on urban animals and rooftop biodiversity) require collaboration. The Lab integrates students from diverse disciplines in real and deeply rooted intervention projects to create sustainable, safe, and fun places (placemaking), such as the creation of the "Story Bench" in Amsterdam.

The ULTLab unites municipalities, tourism organisations, creative industries and residents to co-design sustainable and inclusive tourism experiences. Its iterative experimentation and feedback mechanisms closely align with Proposition 3 (data-driven and adaptive governance) and Proposition 4 (multi-scalar policy coordination):

- Proposition 3 is reflected in the Lab's emphasis on continuous monitoring, feedback and learning loops across participating cities.
- Proposition 4 is evident in its multi-level cooperation structure, which enables knowledge transfer between local initiatives and broader European innovation agendas.

It demonstrates how S4+ principles of openness, evidence-based learning and sustainability integration can be implemented in a cross-regional tourism innovation context.

The three Living Labs collectively illustrate that the core mechanisms hypothesised in the QUH–S4+ model (propositions 1 through 4) are observable, albeit in exploratory form, across distinct governance scales:

- Proposition 1: Environmental and sustainability concerns are integrated into innovation design (ALL, ULTL).
- Proposition 2: Cross-sectoral collaboration is central to knowledge co-creation (SLL, ALL).
- Proposition 3: Data-based and learning-oriented governance emerges through iterative experimentation (ULTL, SLL).

[3] Alimara Living Lab
[4] Urban leisure and Tourism Living Lab

- Proposition 4: Multi-scalar coordination connects local experimentation to national and European policy frameworks (SLL, ALL, ULTL).

Therefore, even though the QUH-S4+ framework has not been institutionalised as such, these efforts offer illustrative proof of its applicability and indicate that its theoretical principles are observable within current innovation activities. They also highlight the potential of Living Labs to act as translational infrastructures between S3 and the broader sustainability missions of European tourism policy.

7. Conclusion

At this point, we are most likely trying to describe a modus operandi rather than a model of analysis. However, some observations may help advance the debate about the challenges of moving towards a QUH structure within S3, and even more challenging is the inclusion of tourism in this transformation.

The essay underlines how the logical structure of the QUH model can enhance the S3 framework by introducing an explicit ecological and societal dimension. It is reasonable to infer that a healthy natural environment combined with participatory governance may balance top-down planning with bottom-up experimentation, especially in the context of the green and digital transitions in tourism, even though no empirical confirmation was undertaken.

Territories fixing their efforts in cooperation, involving various stakeholders and groups of interest in policymaking processes, may create durability for the decisions made. Furthermore, the availability of technology, more specifically concentrating efforts on the green side of tech, helps provide a new approach to studying the tourism domain within S3 towards a QUH framework. Long-term collaboration between researchers, businesses, and users abolishes traditional approaches, and the QUH can value assets that are not assured in a conventional economic paradigm.

The QUH innovation model shows how this societal and environmental change can be successfully handled in tandem with knowledge production and innovation policy by providing a solution-oriented approach to problem-solving and long-term development. In a QUH system, knowledge is not only a factor of production but the driving force of transformation, linking research, governance, and community learning to build cooperation mechanisms for sustainable development (Carayannis & Campbell, 2010a; Provenzano et al., 2018).

The four propositions advanced in this paper articulate how the QUH-S4+ framework may transform S3 into a more inclusive and sustainability-oriented system. The Living Lab examples discussed do not constitute empirical tests of these propositions but illustrate their observability in current innovation practices. They demonstrate that regions and institutions are already experimenting with collaborative governance, sustainability metrics, and cross-regional learning, all of which are essential to the transition from S3 to S4+. Such initiatives provide the proof of concept that the principles of the QUH-S4+ are transferable, measurable, and policy-relevant. They suggest that the path forward lies not in creating new frameworks but in translating existing S3 instruments into a QUH logic that privileges cooperation, ecological intelligence, and adaptive policymaking.

Towards a QUH may enhance the effectiveness of S3 by reducing economic and territorial inequality while capitalising on the spillover potential of tourism. Innovation is no longer limited to technology; it now encompasses sustainability goals and community resilience, as demonstrated by the European Green Deal and the Transition Pathway for Tourism.

The digital-green transition might be accelerated, and tourism's role in regional diversification strengthened by incorporating the QUH rationale into these missions.

Future research should therefore examine the feasibility and performance of QUH-oriented Living Labs, testing whether collaborative ecosystems can deliver measurable impacts on sustainability indicators and SME productivity.

Beyond Europe, comparative studies could explore how similar frameworks emerge under different institutional conditions, thus extending the conceptual reach of the QUH–S4+ beyond EU Cohesion Policy.

Limitations and avenues. Our synthesis is EU-centred and conceptual. Future work should (i) evaluate QUH living labs with counterfactuals; (ii) test S4+ mission effects on related variety; (iii) measure the contribution of the Tourism Data Space to SME productivity and emissions reduction; and (iv) compare EU with non-EU destinations.

To summarise, the relevant feature for understanding tomorrow's tourism is sustainability. Therefore, the foundations of the new tourism model and all S3 strategies must include biodiversity conservation, respect for the sociocultural authenticity of communities, and the guarantee of welcoming countries' social well-being and economic security through the sustainable use of natural resources.

7.1. Contribution & Implications

This paper advances from a descriptive metaphor to an operational governance toolkit for S3; S4+ in tourism. We specify per-helix mechanisms (academia, economy/finance, environment, media/culture/public, policy/governance) as routines, EDP cadence, data-sharing, demand-side instruments.

It also proposes a portable KPI set (CO_2 per bed-night, % renewables in lodging, supplier circularity plans, related-variety linkages, EDP cycle time, cross-border pilots, inclusive jobs).

By translating the QUH–S4+ into a measurable and comparative framework, the article bridges the gap between conceptual research and applied policy design. It supports policymakers and regional authorities in implementing evidence-based, mission-oriented strategies consistent with the Transition Pathway for Tourism and the Tourism Data Space. The approach is particularly actionable for lagging and outermost regions, enabling them to accelerate digital and green adoption among SMEs through open innovation and collaborative governance.

Acknowledging its conceptual and EU-centred limitations, the study outlines a future empirical agenda to test the four propositions (P1-P4), evaluate living-lab outcomes, and quantify the added value of data-space interoperability in sustainable tourism development.

Ultimately, the QUH–S4+ framework aspires to make S3 more inclusive, measurable, and transformative, positioning tourism not as a passive beneficiary of innovation policy, but as an active laboratory for sustainable regional development.

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